EXPLORING SOCIAL PLAY IN A SHARED HYBRID SPACE ENABLED BY HANDHELD AUGMENTED REALITY

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EXPLORING SOCIAL PLAY IN A SHARED HYBRID SPACE ENABLED BY HANDHELD AUGMENTED REALITY

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LIST OF SYMBOLS AND ABBREVIATIONS

AR	Augmented Reality
HAR	Handheld Augmented Reality
WIMP	Windows, Icons, Menus, Pointer
MR	Mixed Reality
VR	Virtual Reality
HCI	Human Computer Interaction
RtD	Research-through Design
EoJ	the Eye of Judgment
HMD	Head-mounted Display
CSCW	Computer-Supported Collaborative Work
AoD	ARt of Defense
FPS	First-Person Shooter
MUD	Multi-User Dungeon
AEL	Augmented Environments Lab
MMORPG	Massively Multiplayer Online Role-playing Games
GUI	Graphical User Interface

SUMMARY

Reality-based interfaces bring new design opportunities to social games. These novel game interfaces, exemplified by *Wii*, *Kinect*, and Smart phones, leverage players' existing physics, bodily, environmental, and social skills. Moreover, they enable a shared hybrid physical-digital space in which the players' co-presence can be enhanced by their physical and digital co-location. However, many digital social games occupy players' attention with the digital display and content, reducing their attention spent on one another and limiting the synchronization of actions and emotions among players. How do we design technologies that do not interfere with social play but enhance and innovate it?

In this thesis work, I focus on one particular kind of reality-based interfaces, Handheld Augmented Reality (HAR), to extend players' interaction from the small mobile devices to the shared hybrid space around a computationally trackable surface. This thesis explores how to encourage social play with HAR interfaces, which brings in challenges of designing with the affordances and constraints of the HAR interface, understanding the complicated phenomenon of social play, and integrating these understandings in multiplayer HAR game design. Adopting Research-through Design as the overarching research method, I collaborate with multiple teams, design and study three multiplayer HAR game prototypes. This work presents five main contributions. First, to game research and design communities, this work provides new design examples about social play in a shared hybrid space, including *BragFish*, *ARt of Defense*, and *NerdHerder*. Second, to HCI and game studies communities, this work enriches the empirical understandings on co-located social play. Third, to sociology and game research communities, this thesis adapts and applies sociology theories to a different area of co-located social play. Forth, to AR and game design communities, this work generates a list of tested theory-based design guidelines for HAR games. Fifth, to HCI and game research communities, this work is a case study on connecting reality-based interface with social play experience in a shared hybrid space. This thesis shows the outcome and benefits of multidisciplinary research, calling for more effort in integrating reality-based interfaces, as playful and experimental design materials, into different phases of game design process.

CHAPTER 1

INTRODUCTION

In the past two decades, novel reality-based interfaces have shifted the cutting edge paradigm of Human-Computer Interaction (HCI) from screen-based interactions, such as command lines and WIMP (windows, icons, menus, pointer), to “reality-based interactions”, in which users leverage their existing bodily, environmental and social skills when interacting with computing devices (Jacob et al., 2008). HCI researchers may use different terms for this type of interface, such as natural interface, physical interface and novel interface etc. What differentiates the new paradigm of computing from traditional user interface is the “embodiment”, which rejects the body-mind separation and acknowledges that we experience the world through the physical body and social understandings (Dourish, 2004). In this thesis I use the term of reality-based interface to refer to interfaces that enable embodied interaction in a physical-digital space.

Reality-based game interfaces have started changing the landscape of the video games industry, exemplified by the success of *Nintendo Wii* and *Microsoft Kinect*. With these examples, reality-based interfaces exhibit advantages in introducing natural and intuitive ways of interacting with digital games, expanding the player demographics to audiences who were not previously considered as gamers (ESA, 2012). Moreover, with these easy-to-learn and intuitive-to-play game interfaces, families and friends enjoy playing together in a shared physical-digital space (Schiesel, 2008). According to the Entertainment Association Software 2011 survey, 65% of gamers play games with other gamers in-person (ESA, 2012).

This space opens up rich design opportunities by leveraging the advantages of both physical and digital co-location (See Figure 1). With physical proximity, players can use their existing social skills, such as facial expressions, body movements, and close observation of other players, to perform better in the game. With digital proximity, players can leverage their digital representations (e.g. avatars) and other communication channels in the shared digital space. With the facilitation of reality-based interfaces, designers can map players' physical action and interaction to their digital meanings in an intuitive manner, connecting both physical and digital proximity in one shared hybrid space. This space opens up new design opportunities and raises new questions: what is the role of the reality-based interfaces in supporting social play? What kind of social play can emerges from the shared hybrid space? Does the physical and digital co-location always lead to better social play experience?

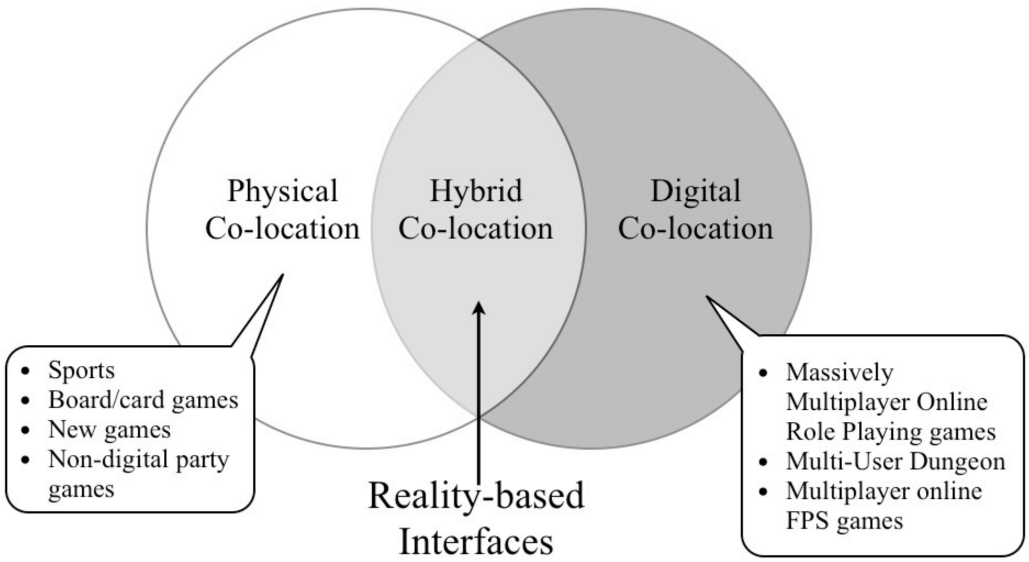


Figure 1. Three unique kinds of co-location—hybrid co-location, enabled by reality-based interfaces, in comparison to games that leverage shared physical or digital space.

Although the design space enabled by players' hybrid co-location has great potential, prior research show that being in the same physical or digital space does not guarantee more frequent or higher quality of social play. For example, in an empirical study of the *Nintendo DS*, one of best-selling handheld game consoles, researchers found that players stayed in their "private sphere" of gaming rather than using the mobile game as a medium for having fun together, even though they were physically sitting next to each other (Szentgyorgyi et al., 2008). Another study on the Massively Multiplayer Online Role-Playing Game (MMORPG) *World of Warcraft* shows the prevalence and extent of social activities in MMORGs might have been previously over-estimated. Other players' presence in this game provides a spectacle rather than frequent social interaction (Ducheneaut et al., 2006). In these games, players' attention is mostly occupied with individual gaming activities rather than with other players. This "alone together" phenomenon happens outside of multiplayer games too. Researchers are concerned that our interaction with technology is replacing the interaction with human beings (Turkle, 2012). With the increased pervasiveness of information technology, it becomes more and more common for people to engage with a shared digital space while being in the same physical space. How do we design technology that leverages the advantages of the hybrid co-location to encourage more social interaction rather than hindering or reducing human-human interaction?

There are many reality-based interfaces that can potentially support enjoyable social play. This thesis focuses on one of them, Handheld Augmented Reality (HAR), to addresses the above research questions and explores the design space of hybrid co-location. Augmented Reality (AR) refers to interfaces that supplement the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world (Azuma, 1997; Azuma et al., 2001)[1]. I choose HAR interfaces as a game interface to study social play with for the following two reasons.

First, in the past decade, researchers have designed and studied how to use Augmented Reality in supporting collaborative work and play. Prior work suggests that augmented reality interfaces can support inter-referential awareness, or the confidence that the communication partners perceive one's references during collaborative work

[1] Other HCI researchers, such as Wendy MacKay and Bill Buxton, used "Augmented reality" as a broader term to refer to how the physical reality of environment, objects and users is linked to virtual reality. But in my work, I use the definition from Azuma, which is widely adopted by the augmented reality and mixed reality research community.

[2] Six "isolate toys" are: Gyroscope (Steven Mfg. Co.), Crayons (Binney & Smith, Inc.), Tinker

scenarios (Chastine, 2007), which is fundamental for effective multi-party communication. Moreover, AR interfaces can leverage natural cues of communication while maintaining independent points of view for individuals (Billinghurst & Kato, 2002). Researchers and designers have developed many collaborative AR systems and applied them to a variety of domains, such as training and learning (Dunleavy et al., 2008), trouble-shooting (Billinghurst, 1998; Feiner et al., 1993) , spatial navigation (Morrison et al., 2009), scientific inquiries (Chastine & Zhu, 2008; Chastine, 2007), emergency management (Nilsson et al., 2009; Prytz et al., 2010), crime scene investigation (Poelman et al., 2012), and multiplayer games (Andersen et al., 2004; Henrysson et al., 2005; Thomas et al., 2000). In short, an AR interface creates a shared hybrid digital-physical space between people, supporting collaboration and communication about the digital-physical objects.

Second, the fast technology development in Augmented Reality has brought it out of engineering labs to the mass market. The first Head-Mounted Display (HMD) system was created in 1965 (Sutherland, 1965). It supported the motion-based three-dimensional perception by responding to users' head movements. However, these systems back then were large, cumbersome, and non-portable. In the 90s, researchers created portable AR systems that users can fit into a backpack and walk around with (Feiner et al., 1997). In the past decade, handheld devices have drastically increased their computational power and camera quality, enabling AR interfaces on-the-go. Along with these technical evolutions is the increase in the game industry's interest in using AR as part of the game interface. The first big commercial AR title, *The Eye of Judgment,* was created for the PlayeStation 3 console in 2007. It was based on a board game and used the EyeToy camera to recognize game cards (The Eye of Judgment™, 2007). Recently, the launch of handheld game consoles from *Nintendo* (the *3DS,* 2011) and *Sony Computer Entertainment* (the *PlayStation Vita,* 2012) presents AR as one of their core novelties in the marketing and promotion. Perhaps more importantly than the adoption by console makers, however, is the increased awareness of handheld AR brought on by the increased power of mass market smart phones, which have the capability to run AR applications and are bringing AR into millions of people's pockets. The prevalence of the AR devices and the emerging AR games call for a deeper understanding on how AR interfaces, as a new medium, affect the user experience that is built on top of it.

While there have been many AR games made by both large companies and indie game developers, designing a AR game which is fun to play, rather than simply showcasing the technology, still remains challenging. Browsing through the list of current AR games, there have been none that have reached a similar level of engagement or user base as successful non-AR game titles. An essential question remains unanswered in the game industry: beyond the initial novelty, what else can AR bring to the table? This is the question that motivates this research, and on which this thesis hopes to shed some light.

Other researchers have designed and developed AR games. However, many of them use games as a vehicle for testing AR technology, usually by making AR versions of existing games. Some of these examples downplay the inherent interdependence between the affordances of an AR interface and the possibilities for gameplay, and it is unclear whether the resulting gameplay experiences are enjoyable, or merely new. Rather than uncritically adopting the stance that "new technology automatically leads to better games", my thesis tackles more fundamental questions about what building blocks comprise a successful social play experience. By focusing on the underlying components of enjoyable social interaction, my thesis takes a player-centric view when designing and studying HAR games.

In this thesis my goal is not only to show what the capabilities of HAR are, but also to explore how to leverage the affordances of HAR to support these components and the process of enjoyable social play. In the game research community, there has been great effort and discussion devoted to this kind of integral role of game interfaces in the bigger picture of game design (Fullerton & Hoffman, 2004; Schell, 2008; Swink, 2009). Montfort and Bogost's book on the *Atari* game platform brought this thread of work into the foreground and explicitly focuses on the "*computational creativity*", drilling down to the specific hardware, software, and peripherals of the gaming platform to understand their role in supporting game design on top of the platform (Montfort & Bogost, 2009). The authors wrote, "*it is time for those of us in the humanities to seriously consider the lowest level of computing systems and to understand how these systems relate to culture and creativity*."(Montfort & Bogost, 2009) In my work, I explore the nascent field of multiplayer Handheld Augmented games with a similar kind of holistic approach that rejects the artificial separation between the computational layers and player experience design.

Research Statement and Questions

This thesis sets out to explore how to encourage social play with HAR interfaces, which brings in challenges of *designing* with the affordances and constraints of the HAR interfaces in mind, *understanding* the complicated phenomenon of social play, and *integrating* these understandings in multiplayer HAR game design.

The core research question driving my work is to understand how a HAR game interface can affect the method used for designing a social play experience and the consequent outcome. To answer this question, I break this question down into four sub-questions:

RQ1. What kind of co-located social play behaviors and experiences are supported by HAR interfaces?

RQ2. What are the underlying components of an enjoyable co-located social gameplay experience?

RQ3. How do theory-based design guidelines support creating enjoyable social play in HAR games?

To answer the above questions, I adopt the Research through Design (RtD) method, which takes design as a core knowledge inquiry method, and aims to *"transform the world from its current state to a preferred state*." (Zimmerman et al., 2007) The RtD method is a good fit for this research into co-located HAR games, for three reasons.

First, game design is a typical experiential design practice that does not have a predefined goal. Game designers may start with a rough direction for the kind of game experience they want to create, but the process is not about solving an existing problem. On the contrary, game designers often need to create new problems for players to solve. This kind of design, referred to as "creative design", "*is about understanding the problem as much as the resulting artifact*" (Wolf et al., 2006). RtD is a method that uses design to explore the problem as much as finding the solution (Zimmerman et al., 2007), making it a good fit for the creative design of games.

Second, the goal of this work is not only to create fun, enjoyable, social games, but also to understand how human behaviors are supported by interactive technologies and game design. In the design process of playtesting, iterating, and user evaluation, I participate in almost every design decision, allowing me as a researcher to gain a reliable perspective on how interaction design is connected with player experience.

Third, there have not yet been any successful commercial co-located HAR game titles that I can directly study during the period of my work. Hence, designing my own HAR games is a necessity.

Using RtD as the overarching research method, this work has three main pillars that feed into the design of HAR social games: Engineering (exploring how to leverage the affordances and design around the constraints of HAR interfaces), Empirical studies (analyzing the actual behaviors that emerge from playing the games), and Theories (deciphering the complicated phenomenon of social play into measurable, observable behavior metrics). In this thesis work, these threads of knowledge are applied to multiple

HAR games. Moreover, the lessons we learned from designing and studying the games also contribute to a deeper understanding of HAR.

Throughout this thesis work, my team and I designed and developed three multiplayer HAR games, I conducted four lab-based evaluations and observations on gameplay experience, and I synthesized a set of sociological theories together to support my data analysis and design guidelines. The research questions and corresponding projects are summarized in table 1.

Table 1: Overview of dissertation research

DATE	RESEARCH PHASE	DETAILS	CHAPTER
Q1: Exploring the space: social play behaviors supported by HAR interfaces			
2007-2008	Competitive AR game: *BragFish*	Research social presence and how different communication channels contribute to it	Chapter 4 (Xu et al., 2008)
2008-2009	Cooperative AR game: *ARt of Defense*	Research how players refer to virtual/physical objects	Chapter 5 (Huynh et al., 2009)
Q2: Understanding co-located social play: theory-based analysis on the compositions of enjoyable social gameplay experiences. Theory-based design guidelines are generated as an outcome			
2010	Theory-based board game experience analysis	Video analysis of the co-located multiplayer board games	Chapter 6 (Xu et al., 2011a)
2011	Theory adaptation to co-located games	Integrating two sociological theories as lenses to analyze existing empirical studies on co-located social games	Chapter 7
Q3: Using theory-based guidelines and study their usefulness: How do theory-based design guidelines support creating enjoyable social play in HAR games?			
2011-2012	*NerdHerder* Design Process/Iterations	Design rationale and process, and how are the guidelines integrated	Chapter 8 (Xu et al., 2012)
2012	Team vs. team *NerdHerder* Study	Research whether and how the design guideline about bodily presence work	Chapter 9

RQ1: What kind of co-located social play behaviors and experiences are supported by HAR interfaces?

The purpose of the first research question is to explore the nascent space of social HAR games, and whether HAR is a domain that can yield the advantages suggested by prior literature. To answer this kind of exploratory question, designing game prototypes is part of the "*methodology for better understanding social behavior and its underlying affordance*" (Gaver, 1996). I participated in the design, and led the studies, of two multiplayer HAR games between 2007-2009: BragFish, which is competitive, and *ARt of Defense* (AoD), which is collaborative. In both prototypes, specific design decisions were made to leverage the affordances of the HAR interface and design around the constraints of this interface. In the studies of these games, I focused on players' actions in this shared hybrid space, such as body positions and movements, object maneuvering, and verbal and non-verbal utterances. These observable behaviors are integral to the gameplay, they are sources of enjoyment and indicators of meaningful social experience. More specifically, I was interested in understanding what the term "shared hybrid space" really means for a group of players of *BragFish*; and I tried to explore how "tangible game pieces" change the way players communicate and interact when playing *AoD*. The user studies of the two games were not designed to obtain feedback about the games themselves, but to use games as probes that help us understand the range of social interactions and physical actions that are an integral part of the game experiences. From the empirical studies, I found a variety of social dynamics and interaction behaviors among the players, many of which are directly supported by the HAR interfaces. The design rationale, game prototypes, and findings from these two studies will be introduced in detail in Chapter 4 and Chapter 5.

The results and evaluation of these two multiplayer HAR games raised four interesting questions, specifically:

1) Players are able to report subjectively how they feel after each game session; how do we tease apart the social enjoyment of the HAR game compared to the general enjoyment from playing games?

2) Social phenomena are complicated; how can researchers extract data that is relevant to the quality of social play?

3) How do we measure the quality of social play?

4) How do we investigate the connection between the game design elements, especially how HAR interfaces are integrated in the design, and the social play experience?

These questions led me to seek methodologies that can support my goal of deciphering the complicated phenomenon of social play, which leads to RQ2.

RQ2: What are the underlying components of an enjoyable co-located social gameplay experience?

From the research exploring RQ1, I draw an empirical picture of the social play experience of multiplayer HAR games. To deeply understand what aspects of game mechanics and interface designs lead to different types of social play behavior, I adopt sociological theories that explain face-to-face interactions and adapt them to the domain of co-located gameplay. Among the wide range of literature, Collin's Interaction Ritual Theory (Collins, 2004) and Goffman's Frame Analysis (Goffman, 1974) are two particularly relevant theories that together provide the tools needed to explain co-located gameplay. Collin's Interaction Ritual Theory is a synthesizing theory that breaks down a social interaction process into four ingredients that may contribute to its success or explain its failure. It is created to understand "the small scale, the here-and-now of face-to-face interaction" (p1, (Collins, 2004)), and aligns perfectly with co-located multiplayer games. But the IR theory does not take in account the co-existing real world and game world that blend together during HAR gameplay. Frame Analysis complements IR theory by accounting for this co-existence.

To test the power of these theories, I use them as lenses to analyze social play of board games. The social play of board games shares much with the play experience of HAR games, so we collected and analyzed video recordings of board game gameplay sessions, to see what makes board games social. Board games are a form of entertainment medium that have been developed for thousands of years. The goal of learning from board game experiences is not to directly transfer the same design choices to digital media, but to understand what kinds of social interactions are encouraged in such games, and how the physical props typical of board game construction support them. For this purpose, the sociological theories provide a useful framework that helps identify which design elements in board games are critical in terms of supporting enjoyable social play.

Using these theories as a conceptual framework, I analyze the empirical studies of co-located games in the recent game study literature. The purpose of the analysis is to 1) adapt the sociological theories to the domain of game study, which is different from the domain where these theories originated; 2) generate design guidelines for co-located multiplayer social games; 3) provide a basis for establishing metrics for evaluating co-located gameplay. Through the process of theory adaption, I propose a new framework for understanding social play experience.

RQ3: How do theory-based design guidelines support creating enjoyable social play in HAR games?

With the design-guidelines I develop by exploring RQ2, the goal of RQ3 is to turn theory-based design guidelines into a running game prototype, *NerdHerder*, and test the usefulness of these guidelines through observing and understanding inter-personal behaviors and experiences during gameplay.

NerdHerder is a two-versus-two team-based competitive game, which differentiates itself from *BragFish* and *AoD* by the different social structure imposed by the game: it is a sport-style donut-feeding game where two teams compete to feed the shared target. Halverson summarized four powers of theory in CSCW research, including descriptive power, rhetorical power, inferential power, and application power (Halverson, 2002). The *NerdHerder* design uses the application power of the sociological theories. Among the design guidelines generated from adapting sociological theories to co-located games, I choose a subset of five that I consider most relevant to HAR game interfaces, including "natural mapping", "motivating the use of hybrid presence in the game", "shared game objects/activities that are affected by players", "motivating players to pay attention to each other", and "game-generated emotion stimuli." These guidelines are implemented into concrete design choices embodied in the game. Moreover, these guidelines are not just high-level goals; they are integrated with every aspect of the game, such as aesthetics, creativity and subjectivity of designers, and the design process. For example, in the design process of *NerdHerder*, theories-based design guidelines help us interpret playtesting feedback and prioritize it. It gives designers lenses through which to critique and iterate the design.

I conducted a lab-based user study to find out how players interact with each other, how these inter-personal behaviors are associated with guidelines, and what the roles of the HAR interface are. The purpose of the user study of *NerdHerder* is to understand these qualities of the design and the usefulness of the design guidelines. As a designer, I need to understand if players enjoy the social play or not. As a researcher, I aim to find the relationships between design choices and user behavior. In the surveys and interviews, players reflected on the game experience and rated it to be enjoyable and social. Through observation and video analysis of the gameplay sessions, I found the players exhibited a wide variety of inter-personal behaviors while playing *NerdHerder*. Being in the shared physical-digital space, *NerdHerder* players frequently used verbal communication (e.g., to coordinate, to help, and to trash talk) and body movements (e.g., to move closer and further to other players, zoom the camera phone in-and-out) as part of the gameplay.

The rich variety in inter-personal behaviors, the depth and novelty of the strategies that players adopted, the frequency of coordination and assistance behaviors, and the oftentimes elevated emotional synchronization suggest that *NerdHerder* is a fun, engaging, social game. This in turn shows that the theory-based design guidelines are indeed useful in design practice. Note that the goal of the user study is not to approve or disapprove the theories itself based on the outcomes of one game. In fact, Gaver elaborated on the "unfalsifiability" nature of theories in design—"*Assertions that X will sometimes lead to successful outcomes, however, are unfalsifiable.*" (Gaver, 2012) He further argued that, "*The notion of making falsifiable statements, or of arranging tests to refute such statements, runs against the grain of the methodological approach of research through design.*" (Gaver, 2012) In the same vein, the theory-based design guidelines are useful to my work because they are generative and aspirational.

In the end of the thesis, I reflected on the design and user studies of the three game prototypes created during this thesis work. This reflection highlighted five conceptual constructs that are found to be useful when designing for social play in a shared hybrid space, including: co-presence, mapping, intention, attention, and emotional contagion. They also provide lenses for designers and researchers to frame the problem, figure out solution, and support communication with their communities.

Contributions

This work sits at the crossing between multiple research and practice communities. It contributes to the HCI, game research and design, sociology, AR communities in the following ways.

1. *To game research and design communities*: providing new design examples for multiplayer HAR games in a shared hybrid space

The three game prototypes created during this thesis embody our understandings, knowledge, inspirations, and engineering capabilities. The artifacts themselves carry this rich amount of information and speak to game designers and researchers directly. Other designers can create new games by reviewing, critiquing and learning from these games.

They can also conduct studies on games that have been released in the application stores (e.g., *NerdHerder*) to answer their own research questions.

One of the critical criteria for evaluating the quality of an interaction design research contribution is the process. By documenting the design processes, methods, rationales, and iterations, I share with the design and research community the design process of each of the game prototypes. The design process of my projects may contribute to rethinking the current prototyping and iterating methods for digital games.

2. *To HCI and game studies communities*: enriching the empirical understandings on co-located social play

The HCI and game studies communities are interested in understanding how new interfaces support and transform user experience and human behaviors. Based on empirical data, including lab-based experiments and frequent playtesting, this research provide detailed and rich accounts of the anticipated and emergent social interaction behaviors that happen within a shared hybrid AR space.

3. *To sociology and game research communities*: adapting and applying sociology theories for co-located social play

The theories that I borrowed from sociology are about face-to-face human behavior in unmediated interaction situations, including verbal and non-verbal behaviors. By adopting and adapting such theory for mediated face-to-face interaction, I extended or modified some aspects of the theory for the new social interaction setting.

4. *To AR and game design communities*: generating a list of tested theory-based design guidelines for HAR games

AR is a nascent and fast-developing domain. Many researchers and practitioners are trying to adopt this style of interface for their specific designs. My work speaks to game designers who are interested in leveraging AR interfaces to create fun, engaging and social experiences. The theory-based guidelines provide a foundation and starting point for designing such applications and games. By using the design guidelines in my own work, I demonstrate how these guidelines can be applied in the context of game design. The usefulness of these design guidelines is demonstrated based on player experience evaluation. In a broader sense, my work may be useful for designers who are interested in creating games that seamlessly integrate virtual and digital objects with the physical environment.

5. *To HCI and game research communities*: a case study on connecting reality-based interface with social play experience in a shared hybrid space

Although game designers and commercial games are actively adopting many reality-based interfaces, the HCI research related to such interfaces does not easily transfer to the domain of game design due to differences in goals and values. Beyond usability, a game needs to fulfill playability and social play goals. My work takes one type of reality-based interface (HAR), and reports the challenges encountered and solutions developed when designing such games.

Moreover, my work adopts the research method of Research through Design (RtD), which was created in the context of HCI and interaction design, to a different context of game design. This approach emphasizes the combination of engineering, empirical study, and theoretical efforts to gain research insights and achieve design goals. This combination of multi-threaded work has proven to be useful in this research with HAR games and can also contribute to other game design projects that leverage reality-based interfaces.

CHAPTER 2

RELATED WORK

In this chapter, I am going to discuss three threads of related work:

- *Design technology to transform social experience.* With the emergence of communication and interaction technologies, the goal of design is not to mimic face-to-face interaction, but to transform it by leveraging the capabilities of the new technology. Online social games are a good example of how the co-evolution between people and technology create a rich diversity of online gaming cultures. Similarly, reality-based interfaces open up new design opportunities for shared digital-physical spaces, blending the virtual with the real. To explore this space, the methods, concepts, and knowledge from HCI provides insights and inspirations to my work.
- *Tabletop digital-physical games.* One subcategory of reality-based interfaces is the tabletop interface that shares an interactive surface and the space around it. Handheld Augmented Reality provides one type of tabletop interface. This section surveys existing tabletop digital-physical games with a focus on the social play.
- *Social play.* The goal of my research is to enhance co-located social play. The definitions and research methods for social play vary in different research communities. Combining this literature provides a foundation for my work to evaluate and design for social play experience. In particular, I discuss the concept of “co-location” and the opportunities and challenges that co-location in a shared physical-digital space may bring.

Design to Transform Social Experience

In the influential paper from Hollan and Stornetta, "*Beyond Being There*", they argued that instead of treating face-to-face communication as a gold standard to be emulated in interaction design, we should develop new technologies that provide people with new value that is not possible in face-to-face situations (Hollan & Stornetta, 1992). In the same vein, the goal of this thesis work is to create novel and enjoyable social experiences with a new medium, rather than mimicking non-mediated face-to-face interactions.

Social Games with Digital Media

Online games are good examples of creating emergent social play dynamics that are unforeseen in other media (Brown & Bell, 2004; Ducheneaut et al., 2006; Nardi & Harris, 2006; Pearce, 2006a; Taylor, 2006). Before the prevalence of networking technology, digital games were predominantly designed for a single player, which gave the impression that digital games are solitary activities (Pearce, 2009). With the technology of networking and computer graphics, designers and developers have created numerous online persistent or non-persistent game spaces; players interact with each other through their digital representations (in a bodily or abstract form). A great variety of game genres thrive, such as MUD (multi-user dungeon), MMORPG (massively multiplayer online role-playing games), Online FPS (first-person shooter) games, Social Network Games, etc.

The curiosity of scientific inquiries extended to user behaviors in online social games. Researchers collected and analyzed empirical data on how people behave in these online games, such as *LambdaMOO* (Dibbell, 1998), *Everquest* (Taylor, 2006), *There* (Brown & Bell, 2004), *Uru* (Pearce, 2009), *World of Warcraft* (Ducheneaut & Yee, 2007; Nardi & Harris, 2006; Pace et al., 2010; Schiano et al., 2011), *Counter Strike* (Wright et al., 2002), *Halo* (Xu et al., 2011c), etc. In these studies, one common theme is the connection between players' behaviors and the game's design choices. As Taylor recognized, the design choices coded in the software play a critical role in the social life online (Taylor, 2004). She discussed the digital material that construct players' online bodies and define the capabilities players have to interact with the digital world and express themselves (Taylor, 2003; Taylor, 2004). In her paper, she quoted the comment from Raph Koster about his work on online social games (Taylor, 2004). Koster is one of the prominent game developers and writers (the author of "the Theory of Fun" book).

> "*I really enjoy the fact that I have a job where I have to think about politics and economics and architecture and visual design and group psychology and reward feedback and social networks and user interface design and creative writing so on.*"

As shown in the above quote, the role of designer expands to creating an ecological system that accommodates the emergent nature of online game communities. Booth's GDC talk on how to encourage cooperative play in the game *Left4Dead* gives a sneak peak into the depth and subtly of the design choices that the team has carefully put in the game to encourage cooperative play (Booth, 2009). A recent trend shows that the more social games' design process actively incorporates players' interaction patterns and feedback. The development process of a top-sale mobile game *Fruit Ninja* is a good example (Muscat, 2012). This game was first released in the iOS market with the very basic game control (swiping gesture to cut the fruit). After collecting feedback from online comments, designers selected features that added the most value to the gameplay and made regular update, including multiple fruit bonus, power-ups, multiplayer mode, and so on. The updates retained the interest of existing users and attracted more new users. Moreover, online social games provide new features based on the common practices in player communities. Forums, online comments, and in-game conversations become feedback channels for designers to keep track of user needs. For example, in the car racing game *Forza 1*, team competition was not directly supported in the game, however, players created a team race by repurposing existing functions. They chose the same color between teammates and picked one car from each team to count as the group's performance. Other players could try to protect that car or crash into other teams' cars. In the later versions of the game, designers added this feature in the product, and made team race available to a broader audience (personal communication with the design team). These examples show that the co-evolutionary loop between people and technology is happening at a faster pace in the game industry. Social games, as socio-technical systems, not only transform players' social experience, but also are being transformed by players. This co-evolution between design and human experience is also at the heart of my thesis work, in which the studies on players' interpersonal behaviors contribute back to the design of game prototypes.

While networking technology has turned online digital spaces into a social playground, reality-based interfaces have also started to change the landscape of games in recent years. On the surface, these interfaces change how individual players interact with game systems. Deeper influences come from the blending between digital and physical worlds. By blurring the boundary, the virtual game worlds are integrated with the "authenticity" from real life (Schell, 2010). It challenges the traditional "magic circle" concept that defines play (Huizinga, 1955; Salen & Zimmerman, 2004), raising fundamental questions about "what is play?" and "what is a game?" New game genres are created to play with the boundary of game and real life. Pervasive games extended the temporal, spatial, and social boundaries of a game (Montola, 2005); alternate reality games brings a different layer of meaning to normal daily life activities (Mcgonigal, 2006); gamification tries to change people's behaviors and habits through games (Deterding et al., 2011; McGonigal et al., 2011). These emerging game genres indicate the new vibrant wave of gaming enabled by the new paradigm of reality-based computing. The research and design community has just started to explore this space through experimenting with novel game experience. This thesis work focuses on one sub-area in this space, exploring players' co-location in the shared hybrid space and how to design for it with Handheld Augmented Reality interfaces.

Interaction Design to Encourage Social Play

The core feature that differentiates digital games from other media, such as movies and novels, is its interactivity. This section discusses the literature devoted to understanding the relationship between game interfaces and social play experience, and how to design for social play by HCI methods and concepts.

Interfaces and Social Play

For the same group of players, the objects that they play with induce different quality and quantity of social play. Findings from developmental psychology show that “play materials” significantly influence the quantity and type of social play that occur among children (Quilitch & Risley, 1973)—social play occurred only 16% of the time when the children were provided with “isolate toys”, whereas social play occurred 78% of the time when children were provided with "social" toys[2]. A more recent study added that social toys supported a more equal balance between parallel and cooperative play whereas cooperative play rarely occurred with isolate toys (Ivory & McCollum, 1999).

Researchers have started to explore the relationship between reality-based interfaces and social play experience. Lindley et al. found that the same game (Donkey Konga by NamCo) played with physical interface (Nintendo bongo) creates significantly more amount of social interactions than the gameplay with button-and-joystick based handheld controller (Nintendo GameCube wireless controller) (Lindley, 2008). The authors speculated that this difference is attributed to the information that physical movements display for other players, which may lead to further communication. In the research on exertion interfaces (the physical interfaces that require exertion), Mueller et al. proposed that the arousal evoked by physical interactions could lead to more social

[2] Six “isolate toys” are: Gyroscope (Steven Mfg. Co.), Crayons (Binney & Smith, Inc.), Tinker Toys (Toy Tinkers, Inc.), Jig Saw Puzzle (Milton Bradley, Inc.), Farmer Says Talking Book (Mattel, Inc.), and Play-Doh (Kenner Products Co.); six “social toys” are: Don't Cook Your Goose, Break the Ice, Don't Spill the Beans (Schaper Mfg. Co.), Pick Up Stix, Checkers (Steven Mfg. Co.), and a deck of playing cards (Bicycle Mfg. Co.)

interactions and bonding (Mueller et al., 2003). Bekker et al. designed and studied multiple “interactive play objects”. Through the user study, they found that play objects that are sharable support more social play than those that don’t support sharing (Bekker et al., 2010). This research provide design examples and empirical data that furthers the understanding of why reality-based interfaces seem to be able to support more social play. But with the huge variety of reality-based interfaces and design choices, a more systematic approach needs to be taken to analyze why some social experiences are enjoyable while some others are boring. Based on these understandings a designer can make informed design choices rather than copying successful examples. The complexity of social play phenomena and their relationship with the characteristics of game interfaces motivates this thesis work to combine of the theory-based and empirical data-based approaches. Similar to the above research examples, I also design and conduct user studies on games with reality-based interfaces. Moreover, I introduce theories from sociology to understand the underlying ingredients and process for enjoyable social interactions and use them to guide the design and analysis of social games.

Game Interfaces and HCI

The communities of game interface and HCI have been learning from each other in the past three decades (Jørgensen, 2004; Malone, 1982; Pausch et al., 1994; Shneiderman, 1993). From the 90s, Game design adopts human-centered approach, because there is no concrete external productivity purpose of playing games, and the quality of a game depends on the subjective player experience. HCI researchers and designers also learned from game design and expanded the heuristics for interaction design to include fun elements, such as challenge, fantasy and curiosity (Malone, 1982). As seen in the histories of both domains, the major paradigm shifts in HCI also lead to revolutions in digital game (J.turner, 2010). Recently, the emerging genre of movement-based games is enabled by reality-based interfaces and ubiquitous computing.

To design a good social game, the game requires a solid foundation of usability and playability (Figure 2). Many of the HCI methods and models apply to different aspects of game design as shown on the right side of Figure 2.

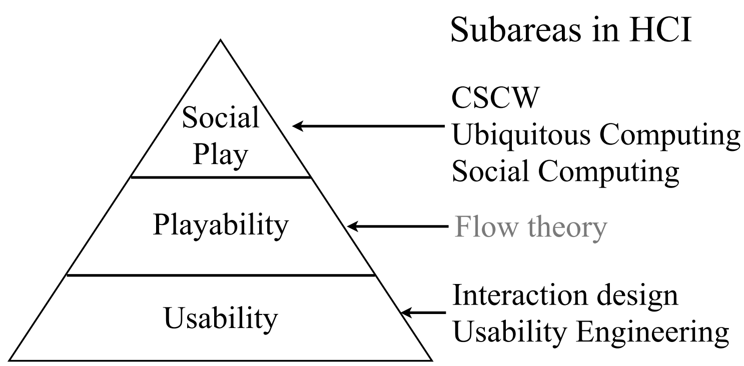


Figure 2. Layers for social game design and corresponding HCI branches. Flow theory is grayed because it may not count as HCI work.

On the bottom level of usability, the interaction design methods and conceptual constructs and metrics and methods in usability engineering can be adapted to the domain of game design. For example, Swink's book of "Game Feel" cites a great amount of HCI literature (e.g. Model Human Processor (Card et al., 1986) and Fitts' Law (Fitts, 1954),) when decomposing the real-time control into the action-feedback-perception loop (Swink, 2009). The models and conceptual constructs from interaction design also applicable to games (Norman, 1988).

Isbister and Schaffer's book, "Game Usability", bridges the gap between research and practice by collecting and synthesizing a myriad of research methods that have been successfully applied in other fields (Isbister & Schaffer, 2008a). A wide range of user study methods, from quantitative to qualitative methods, and from biometric measures (Mandryk & Inkpen, 2004) to heuristics, have been translated from fields like Anthropology, Psychology, and HCI to game research. For example, the research on the heuristics for game usability and enjoyment (Federoff, 2002; Korhonen & Koivisto, 2007; Pinelle et al., 2008) is based on the methodology of usability heuristics in HCI (Andersen et al., 2004).

On top of usability is the playability layer, which is a layer that HCI has contributed the least to the game domain. On this level, certain usability criteria in HCI do not even apply, such as efficiency. In contrast, a good game interface can be “easy to learn, hard to master”. The challenge to master the interface is one of sources of engagement and enjoyment for a game (Juul & Norton, 2009). On this level, the Flow theory (which originated from positive psychology to describe the engaging experience in which one is fully concentrated in an activity and loses the sense of self and time) is widely adopted in the design guideline and evaluation criteria of game experience (Sweetser & Wyeth, 2005 Chen, Gregory, Hsu). The playability of a game is evaluated by its engagement, replayability, and novelty. It is important to be aware of these differences when conducting playtesting and user evaluations on games (Pagulayan et al., 2003).

On the layer of social play, the concepts, models, and design examples from the areas of CSCW, social computing, and ubiquitous computing are useful to social games. Specifically, since my thesis work focuses on the shared hybrid space between co-located players, CSCW is the most relevant to this work. The area of CSCW addresses “how collaborative activities and their coordination can be supported by means of computer systems.”(Carstensen & Schmidt, 1999) From the intial development of CSCW as a field in the 1980s, it has been interdisciplinary—to design computer systems for groups and organizations, the understandings of them (e.g., social psychology, sociology, organization research, etc.) need to be incorporated into computer system design (Grudin, 1994). Technical inventions and novel design created new ways of remote and co-located collaboration, such as media spaces equipped with video and audio systems (Gaver, 1992), tangible interfaces for shared inter-personal space (Ishii et al., 1993a), moving robots to embody remote workers (Venolia et al., 2010), and tabletop surface designed for story telling (Cao et al., 2010). CSCW research advances the understanding on how to use technology to support effective communication, sharing, coordination, assistance and decision making (Gutwin & Greenberg, 1999), which are also the fundamental group activities in many social games. Although most of the CSCW research is for work scenarios, a small subset of it also extends to everyday life situations (Lindley, 2006). For example, Lindley's thesis on the how that sharable interface affect social behaviors in collaborative photo sharing is an example that CSCW applied to homes. She designed a series of studies to understand how the affordances of different interfaces are related to the quality and quantity of social interactions during photo sharing activity among friends. She found that high levels of peripheral awareness, and more equal access to input devices support more equal and interactive conversations and more enjoyable experiences (Lindley, 2006). Similar to Lindley's work, the goal of this thesis work is also to explore the relationship between the types of interactions encouraged by certain interface and inter-personal behaviors. Differently, I take a design-based approach and turn these understandings into specific design choices.

One concept discussed extensively in CSCW is "awareness", which refers to "*an understanding of the activities of others, which provides a context for your own activity.*" (Borning & Travers, 1991; Dourish & Bellotti, 1992; Gutwin & Greenberg, 1996) The design for awareness need to systematically consider the type of information to convey, how users may perceive and communicate it, and when and where to support awareness (Gutwin & Greenberg, 1999). In the context of multiplayer games, the different viewing perspectives that players have may lead to missing awareness of other players. Voida et al. found that co-located console game players verbally communicating about their game states to keep track of other players. They analyzed that this behavior is to compensate for lack of shared awareness caused by the split screen and multiple cameras assigned to each of the players. Similarly, in my thesis work, there exist challenges such as how to support players in constructing a shared awareness with individual small devices viewing the same digital-physical game world from different perspectives. Players communicated through bodily and gestural movements, verbal communications, and observations of in-game events. Detailed findings on these behaviors are reported in chapter 9. These findings resonate with Gutwin and Greenberg's summary of the means of gathering awareness information in a workspace, including bodies and consequential communication, artifacts and feedthrough, and conversation, gestures, and intentional communication (Gutwin & Greenberg, 1996).

The second highly relevant concept for HAR interaction is inter-referential awareness, which refers to "*the ability for one participant to refer to a set of artifacts in the environment, and for that reference to be correctly interpreted by others*." (Chastine, 2007) It was developed based the concept of "*common ground"*, which is defined as *"mutual knowledge, mutual beliefs, and mutual assumptions*" (e.g. a shared set of information between participants) (Gergle & Clark, 2011). The concept of "inter-referential" is important for scenarios when the digital-physical objects (i.e., digital object rendered on top of a marker) need to be referred to for co-located and remote collaborators (Chastine, 2007). Gergle and Clark designed a study in which people collaborate on the task of finding only one piece of artwork from four candidates, and these objects are rendered as digital objects registered on physical markers, viewable through head-mounted displays. The researchers studied how eye gaze overlap and movement in the space affect how users verbally refer to digital-physical objects. Their findings show that if speakers use simpler referential forms (e.g., it, this, that, there, etc.), it suggests that they have the confidence that their addressees have visual (i.e., overlapped eye gaze) or spatial evidence (i.e., body position and orientation) that spot the object they intend to refer to. They also found that whether the users are sitting or moving affects the use of verbal reference and eye gaze overlap significantly. Users tend to include more feature information when referring to digital-physical objects when moving around the board compared to when seated pairs. These finding informed the study design and data analysis, especially for the *AoD* project in which making reference of digital-physical objects is critical to the gameplay (See chapter 5).

The third conceptual construct is the shared space (Benford et al., 1998; Buxton, 1992; Dourish & Bellotti, 1992). The space that CSCW scholars researched included collaborative virtual space (Benford et al., 1998; Takemura & Kishino, 1992), media space (Bly, 1993; Gaver et al., 1995; Root); Collaborative Augmented Environments (Billinghurst, 1998; Ishii et al., 1993a). These “spaces” are essentially “places” that people work and collaborate in, being given the cultural and social meanings an functions (Dourish, 2006; Harrison & Dourish, 1996). This humanistic view on space is grounded in Tuan’s humanistic geography (Tuan, 1977) and Christopher’s discussion on the relationship between events and space (Alexander, 1979). In my work, the shared hybrid space is the arena where social play behaviors emerge. The technology of augmented reality provides new ways people perceive the physical and digital space, move themselves in such a space, and share information and emotion with others. Specifically, to understand how the spatial relationships between human bodies and the physical spatial settings affect interaction patterns, Kendon’s F-formation was introduced to CSCW (Kendon, 2010). Marshall et al. adopted F-formation to analyze how the physical environment and furniture arrangement affected the information access and social interaction among a group of tourists and the information provider (Marshall et al., 2011b). The findings they had with non-technical spatial settings informed their design of sharable digital tabletop surfaces for group collaboration to transform face-to-face interaction (Marshall et al., 2011a).

In summary, the concepts, empirical findings, and design lessons from CSCW are highly relevant to the focus of this thesis work, co-located multiplayer handheld AR games. Specifically, the concepts of shared awareness, inter-referential awareness and space hold their value in the different domain of social play in shared hybrid spaces.

Tabletop Digital-Physical Games

Augmented Reality applications and games do not have to be tabletop-based. But the specific type of technology and design that I focus on is tabletop HAR games. Tabletop digital-physical games involve a shared surface (and the space around it) where the shared digital-physical information is presented. Different reality-based interfaces, such as multi-touch surfaces, tangible user interfaces, projection-based AR, handheld AR, can support this kind of tabletop interaction. With such interfaces, players directly manipulate objects on the tabletop surface to influence the digital world accordingly, and they interact with others in the shared physical-digital space by leveraging their existing social and perceptual skills (Magerkurth et al., 2005; Magerkurth et al., 2004). One of the motivations behind many tabletop digital-physical games is to augment board game experiences with digital media. For example, the mobile multiplayer game of Pirate! uses wireless technology and proximity sensors to turn a physical surface into game space (Bjork et al., 2001). The hybrid board/video game of False Prophets used both sensor technology and handheld interfaces to facilitate social interaction among players (Mandryk & Maranan, 2002). To bridge the gap between physical and digital objects and environments, Leitner created Comino, a tabletop game for children to solve a puzzle by using real and digital domino pieces (Leitner et al., 2008; Leitner et al., 2009). Bakker et al. designed iconic and symbolic game pieces to support the interaction through tangible user interface (Bakker et al. (2007).

The projects and research discussed above created novel interaction and gameplay by taking advantage of the physicality of traditional tabletop games (e.g. board and card games) with the real-time feedback of computational media. In the 70s, there was a wave of interest in studying the logic and math behind board games. The artificial intelligence community also tackled this problem in the 90s, and this era was marked by the success of IBM's Deep Blue machine against the top chess players. More recently, motivated to learn from board games to design better digital social games (Zagal et al., 2006), game research has started to pay closer attention these analogue tabletop games, and analyzed the design elements that support learning (Linderoth, 2011), social interaction (Woods, 2010; Zagal et al., 2006 Woods), and creativity (Costikyan & Davidson, 2011). In relation to my research, non-digital tabletop games share a similar kind of spatial setup with a shared surface and tangible game pieces. My intention was not to copy the successful design element from board games to HAR games, but to understand why non-digital games had made certain design choices and what aspects of social experience they support.

Augmented Reality Games

Augmented reality (AR) is one type of reality-based interface. AR interfaces supplement the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world (Azuma, 1997). With AR interfaces, users can contextualize digital information in the physical world (White, 2009), leveraging real-world physics, as well as their bodily and environmental awareness in the interactions. Moreover, for multiple users, AR enables them to view a hybrid space from their own perspective, while leveraging their verbal and nonverbal cues for face-to-face or remote collaboration (Billinghurst & Kato, 2002; Chastine, 2007). To put AR in a context of the continuum of reality and virtuality, augmented reality is placed in the middle (See Figure 3 (Milgram et al., 1994)).

The goal of AR is not to replace the real world with digital content (this kind of immersive, "Matrix"-like vision was shown in art projects like CAVE (Cruz-Neira et al., 1992)), but to augmented the user, the objects, the environment as needed (Mackay, 1998).

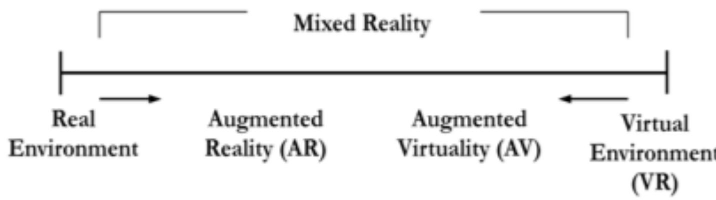


Figure 3. Milgram's Reality-Virtuality Continuum (Milgram et al., 1994)

Researchers have been researching AR since the first Head-mounted Display created in 1960s by Ivan Sutherland and Bob Sproull (Sutherland, 1965, 1968). In the vision that these pioneers brought forward, they sketched out the display that presents content with a perspective change when users move, and the 3D effect of the graphics depends much on the "Kinetic depth effect." (Sutherland, 1965, 1968) AR has been deployed and researched in application domains such as training (Hughes et al., 2005; Livingston et al., 2002; Schwald & De Laval, 2003; Sielhorst et al., 2004), trouble-shooting (Billinghurst & Kato, 2002), emergency management systems (Nilsson et al., 2009), crime scene investigation (Poelman et al., 2012; Sandwik & Waade, 2008), etc. Games are one of the biggest domains that AR interfaces have been applied to. A survey of AR games can be found in (Tan & Soh, 2010), where the authors mapped the games long the dimensions of time, technology and genre. Although many augmented reality games roughly register graphical overlay on real world video based on GPS and Gyroscope data, the subset of augmented reality interface that this thesis focus on are the one with tightly registered graphics.

Figure 4. (Left). The first commercial AR game – the Eye of Judgment™, with two players playing in their living room (cited from IGN.com); (right) Handheld AR game – InviZimals™, with a scene in the trailer.

Figure 5. A collage of commercial and indie HAR games (Top row left: *Paparazzi* by Pixel Punch; Top row center: *EyePet* by Sony Computer Entertainment; Top row right: *ARhrrrr!!* (MacIntyre et al., 2010); Middle row left 1*: Inch High Stunt* Guy by Defiant; Middle row left 2: Candy War; Middle row left 3: *LevelHead* by Julian Oliver; Middle row left 4: *BragFish* (Xu et al., 2008); Bottom row left: Nintendo 3DS build-in AR game; Bottom row center: *NerdHerder* (prior version); Bottom row right: *Rock'em Sock'em* by Mattel)

Currently the most commercialized AR games are on common hardware platforms, such as mirror image based AR with game consoles, and smart phones that have rear cameras. The first AR commercial game title, *the Eye of Judgment*, was launched on PlayStation3 by Sony Computer Entertainment in 2008. With the fast development in hardware capability and computer vision technology, mobile AR games, such as *Invizimals* (2009), *EyePet* (PSP version, 2010), and *Nintendo 3DS AR games* (2011) show the increase of interest in mobile AR interfaces from leading game companies. Indie game developers have also created dozens of AR games (Figure 5), as summarized in (Xu et al., 2011b). Although HAR games do not currently have a large share of the market, Augmented Reality (AR) gaming is beginning to gain popularity with the recently released commercial consoles such as *Sony PS Vista* and *Nintendo's 3DS.*

Much effort from industry and academia has been devoted to building game systems and prototypes. The rapid improvement in the free ARToolkit SDK is one of the drivers that enabled a growing developing community for AR applications (Kato & Billinghurst, 1999). On mobile devices, ARToolkit Plus (Wagner & Schmalstieg, 2007) and StbES (Wagner & Schmalstieg, 2009) increased the performance and lowered the system requirement for AR deployments. The barrier to building AR applications lowered as more and more AR toolkits becoming available, especially on mobile devices (e.g., Qualcomm AR SDK for Android phones (2010), AR SDKs for iPhone (2010)) and on the web (e.g., FlAR, an SDK for building flash based AR applications that use a web camera (2009)). Consequently, interest has shifted from how to build AR applications to how designers can leverage the affordances of AR interfaces.

Multiplayer Handheld Augmented Reality Games

The first mobile AR game running in real time on off-shelf handheld devices is *Invisible Train* in 2004 (Wagner et al., 2004)). Since then mobile AR games have been designed and developed to test research hypothesis and advance the understanding of how mobile AR interfaces can be used in collaborative and competitive scenarios. In

2005, Henrysson et al. conducted a study on a mobile AR Table Tennis game to understand the role of face-to-face collaboration enabled by mobile AR interfaces (Henrysson et al., 2005). The AR research community has studied a variety of topics through mobile AR games, including spatial navigation (Morrison et al., 2009), social presence (Xu et al., 2008), tangible objects (Huynh et al., 2009), eye-gaze between collaborators (Prytz et al., 2010), and inter-personal distance (Oda & Feiner, 2009).

The research above investigates inter-personal behaviors in different user scenarios of multiplayer augmented reality interfaces. They suggest that players can collaborate and communicate with one another using multi-modal interaction during multiplayer AR games. My work integrates these findings on human behaviors into the design of HAR games. However, in my work, the ultimate goal is enjoyable social play, rather than using HAR games to as testing platforms for other collaborative work.

Social Play

Social play predates the invention of games, languages, and even human intelligence (Bekoff, 1974). The term of social play has been used in different domains, including developmental psychology, game research, and user experience research. I combine research from different domains to recognize both the emergent nature of social play and the materials of play as foundations for such behaviors. My research seeks to understand social play as enjoyable and playful interpersonal behaviors, and how it can be triggered, enabled, and changed by design of games.

Social Play As Observable Interpersonal Behaviors

Social play was studied extensively in developmental psychology. Although the purpose of my work is not understanding childhood development of social skills, this community provides rich amount of empirical work and establishes some measures of social play behavior.

Parten observed children's free-play behaviors, and found six kinds of social participation: *unoccupied* (not engaged in play); *solitary play* (play independently); *onlooker* (watching others play); *parallel group activity* (playing with similar objects, clearly beside others but not with them); *associative group play* (playing with others without organization of play activity); and *cooperative group play* (coordinating one's behavior with that of a peer. Everyone has a role, with the emergence of a sense of belonging to a group.) (Parten, 1932). The last four types of behaviors involve different levels of engagement with other players, which are also exhibited in multiplayer games that involve different media and different audience. Although these types of social play are associated with the age difference of children (Parten, 1932), it is not true that one kind is necessarily better than the other. But designers need to be aware of the difference and how to design for each kind of them.

Researchers studied puppies and primates and found that their social play has properties that are similar to social play among human beings, such as pretense, invitational signaling, signaling before and during fighting, and role-reversing and self-handicapping (Bekoff, 1974; Rubin et al., 1978). In Bekoff's research about canids (1974), he characterized social play in a number of ways: (i) actions from various contexts are incorporated into labile (unpredictable) temporal sequences; (ii) the "play bout" is typically preceded by a meta communicative signal which indicates "what follows is play"; these signals are also observed during the bout; (iii) certain actions may be repeated and performed in an exaggerated manner; (iv) the activity appears "pleasurable" to the players. These categories can help researchers identify behaviors that belong to the category of social play. Note that play behaviors are differentiated from real fight by signaling it ahead of time and exaggerated actions, which support one character of social play – "pretend play". Three processes involved in the "pretend play" are adoption of a shared pretend focus for interaction, meta-communication to define the activity as pretend play, and communication within pretend play (Goncu, 1993).

Social Play Emerged from Multiplayer Games

Although social games are not prerequisites for social play, they have been designed for the purpose of generating enjoyable social play. It is of interest to this thesis work to find how the design choices and set-up of social games may trigger and support social play. Social games encompass a large set of games with different genres. In following table, I categorize social games along the dimensions of time and space (See Table 2). Note that the same game can be played in different time and space settings. For example, Voida et al. researched how players enjoy console-based games synchronously in a shared space, although some of the games they played were MMOGs.

Table 2: Social games categorized by time and space.

Remote	Multiplayer Online Games (MMOG) (e.g., World of Warcraft); Multi-User Dungeon (e.g., LambdaMoo)	Play-By-Mail (PBM) (e.g., Correspondence chess); Asynchronous facebook games (e.g., Farmville)
Co-located	Board/card games; “New Games”; Arcade games; Tabletop digital games (e.g. Eye of Judgment, InviZimals); Ad-hoc networked mobile games	Exquisite Corpse (a drawing game that players take turns to draw on the same piece of paper. But everyone can only see the edge of last person’s drawing)
	Synchronous	**Asynchronous**

In my work, I focus on the cell of co-located, synchronous games. This choice of focus is based on three reasons. The first reason is the importance of face-to-face social play. For decades, researchers from developmental psychology have researched the critical role of social play in a child’s cognitive development (Parten, 1932; Piaget, 1962;

Smilansky, 1968). Co-located social games provide a safe environment for children to learn cooperation, trust and fairness (Bekoff, 1984). Beyond the roles of supporting child development, social play provides an enjoyable experience that is shared and enhanced among multiple players. Compared to human-computer character interaction, Mandryk et al. prove that co-located human-to-human interactions are more enjoyable, both by self-rated feedback and physiological data (Mandryk & Inkpen, 2004). Handheld devices, such as mobile phones and handheld game consoles, provide a portable and affordable platform to play such games. The second reason is the growing interest in leveraging natural interfaces in co-located games. The success of the Wii and Kinect showcase the enjoyment of physical and social play during co-located games. With the growing popularity of "reality-based interfaces," the game industry has been developing new game interfaces that incorporate the full body and active movements by the players (e.g., *EyeToy*, *Wii*, *Kinect*). In academia, a variety of game interfaces are being measured and compared for the purpose of enhancing player engagement and increasing social interactions. Prior work has studied the connection between reality-based interfaces and the amount of social interaction (Lindley, 2008), social bonding (Mueller et al., 2003), and social presence (Xu et al., 2008). My thesis is also along the same line of understanding the effects of reality-based interfaces. Based on the above reasons, I believe that researching collocated social game play experience is important and timely.

The choices of game interface and design are not the only factors that would affect the quality and amount of social interaction. The context of play also makes a significant difference, including the social actors (who to play games with), space (where to play) and time (when to play and how long the play lasts). I believe that these factors are also an important influence on the game experience and the quality of social play. However, in this thesis I focus on examining the effect of game design and how it impacts the social play experience. Therefore, all of the experiments that I plan to conduct will control these other factors when possible, and give clear descriptions of the context for the conclusions that I draw.

Prior research of empirical studies on games is highly relevant to my work. Recently, HCI and CSCP (computer-supported collaborative play) communities have shown a surge of interest in adopting user experience research methods to understand collocated social gameplay (Seif, 2010; Voida et al., 2010). Video games are being investigated as cooperative, collaborative and competitive systems (Seif, 2010; Szentgyorgyi et al., 2008; Voida et al., 2010). Voida et al. observed gaming practices that players enjoy as an individual and a group, pointing out that a players' focus may shift between group activities and individual activities (Voida et al., 2010; Voida & Greenberg, 2009). Seif et al. create a set of Cooperative Performance Metrics (CPM) to evaluate cooperative play experiences, including: "Laughter or excitement together," "Worked-out strategies," "Helping each other," "Global strategies," "Waited for each other," and "Got in each other's way." (Seif El-Nasr, 2010) Bell et al. studied how mobile pervasive games were interwoven into players' everyday life in a one-week study of the gameplay. They found a variety of social interactions within and out of the scope of the game (Bell et al., 2006). Inspired by this research, our research on board games also uses empirical methods to understand the emergent behaviors players may have when playing social games.

The research methods used in the empirical studies vary, including reflection-based (Voida & Greenberg, 2009), participatory (Nardi & Harris, 2006; Pearce, 2006b), obseravations and video analysis (Seif El-Nasr, 2010), and physiological data (Mandryk & Inkpen, 2004; Mandryk et al., 2006). *Reflective methods* include interviews for individuals and groups of players. *Observational* studies include observation notes (e.g., spatial layout is one kind of observation note (see Figure 6)) and video analysis. *Participatory studies* are based on ethnographic methods and the researchers join player community as part of them. *Physiological data* are the quantitative data that researchers collect, such as galvanic skin response (GSR) and electromyography (EMG), to indicate levels of arousal and tension during a computer game. In my own work, I collected multiple sources of data, including survey, game log, observation notes, video analysis, interviews to study the HAR game experience from multiple perspectives. While the observation and video analysis is conducted through the perspective of researchers, interviews and surveys reveals the subjective experience from players' perspective. These multiple data sources triangulate each other in the data analysis process. I also found the top-down view that marks the relative positions of players (Figure 6) a useful approach when trying to understand how the interpersonal movement, distance, and orientation affect the social experience (Kendon, 1970). Therefore I collected the top-down videos in the study with *NerdHerder*, and it yielded useful data about players' movement.

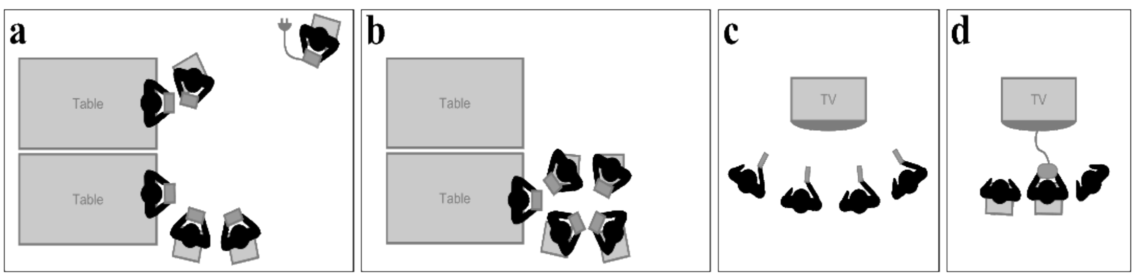


Figure 6. Physical layout observed at a gaming event: a) 6-player Mario Kart on DS; b) 5 people playing Pokemon on DS; c) 4-player Wii Sports on a console; d) 3 people taking turns at 1-player Donkey Konga on a console. Cited from (Szentgyorgyi et al., 2008)

This interest in studying social play in video games is encouraged by the shift from single to multiplayer player video games. With the development of networking technology and everyday computing, multiplayer digital games are viewed as "*a return to the natural order of things*" after the paradigm of single player video games (Pearce, 2009). However, the prevalence and depth of social interactions are found to be over-estimated in massively multiplayer online games (MMOG), where players control their avatars and interact with other player's avatars. Players are more likely to be playing "alone together", and they tend to have more "spectator experience" rather than direct interaction (Ducheneaut et al., 2006). This lack of social interaction in multiplayer online games points back to more traditional games, such as board games and sports, in which more face-to-face social interactions are involved. One of the most important elements of these game experiences is the shared physical space where people can express themselves using the full range of human social and physical abilities, which is seen as one of the features of AR interfaces. However, the physical co-location between players does not always lead to more enjoyable social play (De Kort & Ijsselsteijn, 2008). As found by Szentgyorgyi et al., social interactions between players with the Nintendo DS are actually less than traditional console gaming due to the lack of a shared display, the reduced potential for spectators, and the closed nature of game play experience (Szentgyorgyi et al., 2008) . Their research showed that there is much room to improve for the social play of current multi-player handheld games, providing a niche for AR handheld games to fill.

Co-location in Social Games

We use the lay term "co-located games" to refer to games people play together in the same physical space, for example, sports, board games, and party games. With the introduction of digital media, players can be mapped into digital representations. In online games, players share online digital spaces with others' online representations. In other worlds, they are co-located in the online digital space, for example, in MMORPGs, MUD, and Online FPS games. With the reality-based interfaces being adopted in game design, exemplified by the success of Wii, game industry has begun to reemphasize the co-located fun, but with the layer of digital games mixed in the physical space. In these games, players sit together and enjoy competing or collaborating with their friends and families in the digital games. I refer to this kind of co-location as "hybrid co-location" (See Figure 1) in this thesis.

Game researchers have pointed out that being co-located in the same physical space or digital does not guarantee enjoyable social play (De Kort & Ijsselsteijn, 2008;

Ducheneaut et al., 2006). The sense of being together, which is referred to as "co-presence" are not necessarily high with physical or digital proximity. In fact, many existing digital social games are designed for players to sit or stand shoulder-by-shoulder facing the monitor, not each other (so called sociofugal setting by Sommer (Martin et al., 2001)). However, being physically co-located does enable multi-channel interaction and a faster feedback loop. In the direct face-to-face interaction situations, co-location allows people to use their existing social skills to keep close track of what others are doing and respond to it immediately, which also supports emotional contagion effectively (Collins, 2004; Goffman, 1967; Hatfield et al., 1994; Isbister, 2010). Many non-digital co-located games, such as Mafia and Little Max (analyzed in (Salen & Zimmerman, 2004)), require players to pay close attention to others' facial expression and intonation in the gameplay, leveraging the social skills that players possess. Co-location supports players in leveraging their social skills to keep in tune with other players' actions and make informed decisions based on the observation.

When players share both the digital and physical space together, there are more communication channels they can use. De Kort et al. summarized three types of them among social game players; each provides different means of communication (See Figure 7 cited from (De Kort & Ijsselsteijn, 2008)). The sociality characteristics of the setting shape the interpersonal dynamics and social mechanisms at play (De Kort & Ijsselsteijn, 2008). In games with reality-based interfaces, the shared hybrid space enables the communication channels in digital and physical spaces. But a pitfall for game design is to rely completely on the virtual representations of players, ignoring the advantages that physical co-location can bring. The hybrid co-location requires intuitive and identifiable mapping between the physical actions and in-game game state change. This mapping can encourage players to use their existing social skills in the physical world to enhance their gameplay experience.

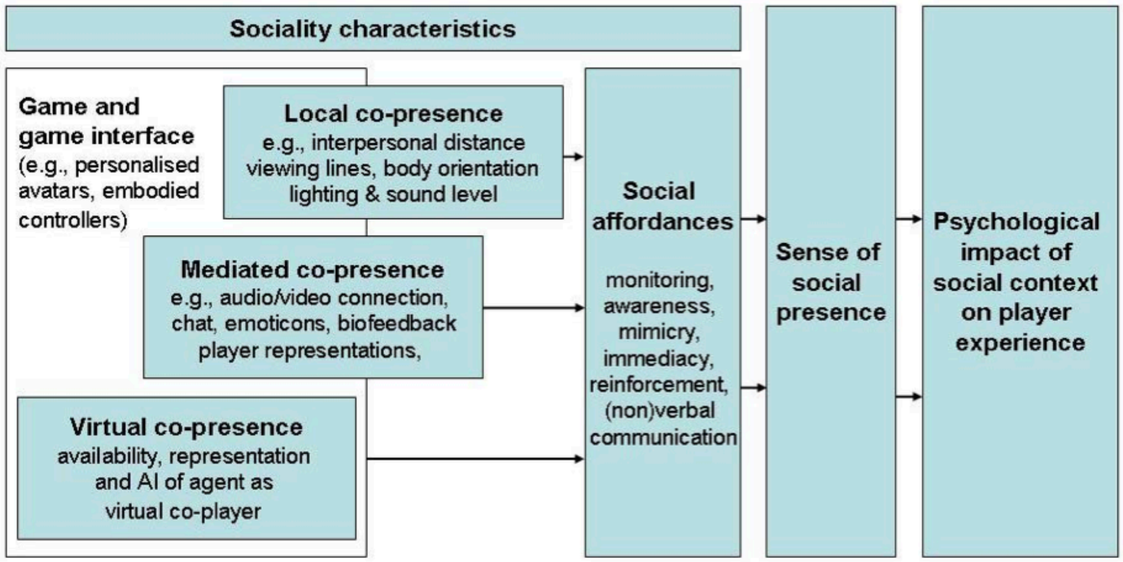


Figure 7. Framework for game setting's sociality characteristics for player experience: different forms of co-presences (Cited from (De Kort & Ijsselsteijn, 2008)) Note that they use co-presence differently than this writing. In my work, co-presence refers to the subjective experience of "being there together" (Schroeder, 2002; Zhao, 2003). In this framework, the co-presence refers to the means and communication channels that may support the sense of being together.

In online social games where players leverage their virtual proximity (mainly through the digital body or other forms of representations of online players) and mediated communication (mainly through audio/video/txt-based communication), players have started to adopt the online space and turn them into the "third place" where they hangout and socialize (Steinkuehler & Williams, 2006). Players make intentional choices with their digital body and its customizations. These decision-makings around the digital body make a "'tangible embodiment of their identity" (Ducheneaut et al., 2009). Researchers found that the features of character customization that players spend the most attention on are the ones visible and recognizable to other players, such as hair (Ducheneaut et al., 2009). Furthermore, the choices of digital bodies in online game spaces may affect a player's behaviors in the real world ("the Proteus Effect") (Yee et al., 2009). This finding shows the social need of presenting oneself in front of others applies not only to real world (Goffman, 1959), but also to the online worlds. The digital bodies may affect players' real-world behaviors.

In summary, the three different kinds of spatial setting between players enable different communication channels. The need to present oneself in front of a social game is an innate need in both digital and physical worlds. To design games that leverage hybrid co-location, the game needs to support the natural mapping between digital and physical actions, and encourage players to use their existing bodily and social skills.

Summary

The above three research threads lay out the foundation for my own work. The first thread of research, design to transform social experience, provides examples and evidences of how new technology changes the existing practices and experience of social interaction. It is shown in the digital game history that networking technology has changed the landscape of social games. In the CSCW context, new paradigms of human computer interfaces have changed the workflow as an outcome. These are examples how technologies not only support human-human interaction but also transform it. My thesis shares the goal of transforming social experience by leveraging reality-based user interfaces, focusing on creating new experiences rather than mimicking face-to-face interactions.

The second thread of related work, tabletop physical-digital games, reviews exiting games that design for interactions and social interactions around a table. Many of these games are experimental and explorative in nature. They may not fit with a successful commercial game profile, but they create new inter-personal player behaviors and experiences that emerge from a shared hybrid space. Similar to the multiplayer HAR games I create, these games show the integration between what a reality-based interface is capable of doing, and what kind of game experience a designer targets to create the game.

The third research thread explores social play for its meanings in different domains. Combining perspectives from different research communities, social play is both interpersonal behaviors and an outcome of multiplayer games. This dual nature of social play during multiplayer games shows that it is not just player behaviors or designer intention, but interplay between both. This stance on social play is kept throughout this thesis.

CHAPTER 3

RESEARCH METHOD

The overarching research method I adopt in my thesis is Research through Design (RtD). This method takes design as a critical knowledge inquiry method. In my work, the goal of interaction design is not only to make enjoyable social games, but also to deepen the understanding of co-located social play in the new field of reality-based computing. The research activities in this thesis include designing and developing game prototypes, empirical studies, and theoretical analysis. This thesis is a multidisciplinary work that draws influence from the domains of human-computer interaction (HCI), game studies, sociology, and design research. Throughout my research, I adopt and adapt a myriad of qualitative and quantitative research methods in order to understand co-located social play and design for it with the reality-based interface of Handheld Augmented Reality.

In this chapter, I first introduce Research through Design (RtD) method and explain why I choose it. I subsequently discuss each of the research activities performed under the umbrella of the RtD method, including design (prototyping, playtesting and iterations, HAR interface as design material, and theory-based design), empirical data collection and analysis (observation, video analysis, game logs, interviews, and surveys). Finally, I discuss the expected outcome of this RtD research and how to evaluate it.

Research-through-Design

Research-through-Design (RtD) acknowledges interaction design as a research method that transforms the world from current state to a preferred one (Simon, 1996) and produces knowledge through design artifacts and processes (Cross, 2001). Proposed by Zimmerman et al., the framework of RtD (See Figure 8) lays out research activities and agenda for projects that engages "wicked problems", which are "*ill-formulated, where the information is confusing, where there are many clients and decision makers with* *conflicting values, and where the ramifications in the whole system are thoroughly confusing*" (Rittel & Webber, 1973). As the interest of HCI moves from usability to user experience, designers and HCI researchers encounter more and more such kind of "*wicked problems*". RtD work requires multidisciplinary efforts, including the input from engineers, anthropologists, and behavioral scientists, to feed into the interaction design and produce design artifacts that embody the multiple threads of knowledge.

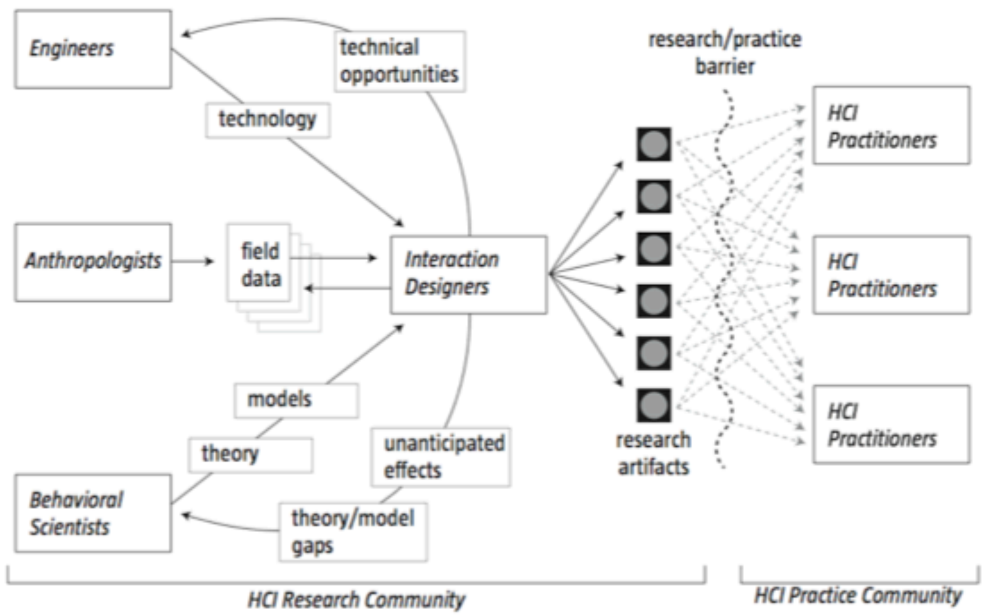


Figure 8. The RtD model: pathways and deliverables between and among Interaction Design Researchers and other HCI Researchers. (Zimmerman et al., 2007)

The concept of Research-through-Design (RtD) was first advanced by Christopher Frayling in 1993 (Frayling, 1993). Zimmerman, Forlizzi and Evenson reintroduced this concept to HCI community to address the problem of the community "*lacking a unified vision of what design researchers can contribute to HCI research*." (Zimmerman et al., 2007). Interaction design in HCI research has been often treated as "*black art"*(Wolf et al., 2006), where the process and thinking of interaction design remain hidden. The underrepresented amount of design in research literature indicates the discrepancy between the metrics for evaluating research and design. As pointed out by Fallman, "the *design process tends to remain implicit as researchers are embarrassed by not being able to show evidence of the same kind of control, structure, predictability and rigorousness in doing research as they are able to show in other parts of their research.*"(Fallman, 2003) RtD, although still under rapid evolution itself, provides a framework and a set of criteria for the interaction design community to conduct studies and report on their design, to provide insights to the community. Rooted in design research, HCI, and interaction design, RtD focuses on the role of design in knowledge inquiry - it is a "*systematic inquiry whose goal is knowledge of, or in, the embodiment of configuration, composition, structure, purpose, value, and meaning in man-made things*" (Archer, 1965)

Choosing RtD for My Work

I choose RtD to be the overarching research method for this thesis for the following two reasons. *First*, RtD recognizes interaction design as a core knowledge inquiry activity. My research depends significantly on the design and evaluation of game prototypes. Just as it is not possible to discuss the effectiveness and efficiency of user interfaces without knowing the tasks that it aims to support, it is hard (if even possible) to discuss the relationship between game interfaces and player experience without having game artifacts that embody that relationship. Game experience is the interplay between designers and players (Schell, 2008). While my role as *researcher* is to study what social play behaviors emerge from multiplayer HAR games, these behaviors will not otherwise exist without certain game design. My other role as *a game designer* is to create capabilities to enable players to communicate and express themselves. Knowing the design rationales and choices behind the game artifact is essential for interpreting players' behaviors. Moreover, I choose to design new multiplayer HAR games instead of studying existing game artifacts because 1) there have not been genre-defining multiplayer HAR games available yet. Although two commercial AR games that support co-located game play *(the Eye of Judgment* and *Invizimals*) have been published, these two games have been critiqued for not fully leveraging the advantages of AR (Remo, 2007). Other game designers and researchers are also currently exploring this space; and 2) making conscious design choices that embodies these insights based on the best knowledge of designers (Gaver, 2012). These choices are fundamental to understanding the expected and unexpected user behaviors.

Second, I chose RtD because it is a good fit for the "creative design" nature of games. In contrast to "engineering design", which has well-defined problems to solve, creative design is an interplay between problem setting and problem solving (Cross, 2001) (Löwgren, 1995).

> "In this interplay, the design space is explored through the creation of many parallel ideas and concepts. The given assumptions regarding the problem are questioned on all levels. Creative design work is inherently unpredictable. Hence the designer plays a personal role in the process." (Löwgren, 1995), P87

In creative design, not only can the problem framing and design goals be decided by choice, but the solutions also vary greatly without a definitive answer of what is "right" or "wrong" (Cross, 2001). This interplay between "problem" and "solution" is especially true for game design since the goal of games is to create profound human experiences rather than supporting an external goal. Unlike a User-Centered Design approach, where the design process starts with aiming to understand an existing problem domain, game designers rarely try to "solve" an external problem; they are more about creating problems for players to solve or to reflect on. In my research, for example, although the goal of encouraging social play is clear, deciding what multiplayer game to design is not trivial—it involves careful investigation of several different aspects, such as the medium (i.e., Handheld AR interfaces), characteristics of interpersonal behaviors, and existing practices of social games. The role of design in my work is not merely to provide solutions, but to integrate collaborative efforts, knowledge, skills, resources, and inspirations into game artifacts, to create novel and enjoyable experiences for players, and to reveal the dimensions of challenges involved in making this kind of HAR games.

Components of RtD and Research Activities

As shown in the model in Figure 8, RtD is a multidisciplinary effort: "*Using the model, interaction design researchers integrate the **true** knowledge (the models and theories from the behavioral scientists) with the **how** knowledge (the technical opportunities demonstrated by engineers). Design researchers ground their exploration in **real** knowledge produced by anthropologists and by design researchers performing the upfront research for a design project.*" (Zimmerman et al., 2007) In summary, the multidisciplinary work of RtD grounds the design with the "true", "how", and "real" knowledge. These are specified in this thesis as follows:

- "True" knowledge: Theories and models on micro-level social interactions.
- "How" knowledge: Affordances and constraints of HAR interfaces
- "Real" knowledge: Empirical findings on co-located social play, especially on HAR games

These different intellectual heritages are embodied in the HAR games we designed and developed. In total, my team and I designed and studied three game prototypes, including *BragFish*, *ARt of Defense (AoD)*, and *NerdHerder*. While each of the prototypes is a result of iterative design, between the prototypes, we learned lessons from the previous games and integrated this new knowledge in the design of the next prototype. The first prototype, *BragFish*, was mostly explorative. It was inspired by the opportunities that the novel HAR interfaces provide. Through designing BragFish, we gained more knowledge on *how* to turn the affordances into game features and design around the technical constraints. The user study on *BragFish* yielded more "real" knowledge about players' interactions during HAR games, which informed the design of the *AoD*. Both prototypes and their user studies, enabled us to gain more "how" and "real" knowledge of designing HAR games which was put to use in designing the third game of *NerdHerder*, where we also investigated more from a theoretical perspective. The process of designing and developing multiple prototypes is a process of deepening the understanding of social play.

The two major research activities that I conducted in my thesis include design and user studies. Each of them includes a myriad of methods, as described below.

Design Methods

Fast Prototyping, Iterating and Playtesting

"*Prototyping lies at the heart of good game design*." (Fullerton & Hoffman, 2004) Prototypes are crude but functioning systems for designers and users to playtest and critique. The techniques for prototyping include sketches (Buxton, 1992), paper and software prototyping (Fullerton & Hoffman, 2004). In the three HAR games, my team and I have tried out these methods and refined our process for prototyping HAR games to make it more efficient and effective.

We started the first project of *BragFish* by following the procedural steps of conceptualization, writing the design documents, paper prototyping, iterating on the paper prototypes, software prototyping, and playtesting. The process of prototype on the medium of paper took a relatively long time, but many of the features in the paper prototyping phase could not be transferred into the software. We encountered a series of software and hardware constraints when starting to prototype with the Gizmondo platform. There was no game engine available that could support 3D graphics on such mobile devices at the time, and the frame rate of AR applications such as ARToolkit (Kato & Billinghurst, 1999) (Wagner & Schmalstieg, 2007) (and later StbES tracker (Wagner & Schmalstieg, 2009)) was low on the state-of-art devices at that time (12-15 frames per second). Moreover, the "game feel" (Swink, 2009) of real-time HAR interface, which requires players to look through the window of a phone screen and move themselves around the game board, is fundamental different from that of paper-based prototypes, in which the main kind of interaction is to grab game pieces and place them on the board. The different medium leads to different bodily actions and feedback loops. We start to consider HAR as a different material for design that need the prototyping process to fit with users' embodied actions and interactions enabled by the HAR interface.

These design lessons were further verified through the interview and observation with students who took the class of HAR games in 2008 (Barba et al., 2009). We analyzed the interview data and design products from the class, and came to the conclusion that to prototype HAR games, a better design process is to start with the core game control implemented on handheld devices and iterate it thoroughly to make it feel natural, intuitive, and fun. Projects with extensive design documents based on paper prototypes tended to fail because the core enjoyment of the game was lost when transferring from a medium where people mainly sit and take turns to place objects, to a medium that players move around and constantly interact with the digital game world. The scope of the project was hard to manage because it was a lot faster and easier to prototype with paper medium, but very slow with the state-of-art software support for HAR interfaces.

In the project of *NerdHerder*, the design process is highly iterative and relies heavily on playtesting when there were conflicting design choices among designers. The first core game control was implemented in just two weeks, and playtested and iterated for many rounds. The playtesting started with our own fellow colleagues and friends. When major changes are made or milestones were achieved, we broadened the range of playtesting to strangers on the street (Muscat, 2012) and students from other disciplines in the university. Also, my team and I submitted demos to conferences to show the game prototypes to an international audience. During the demos, we encouraged players to experiment with the game and observed differences between novice and expert AR interface users, as well as people who consider themselves as gamers and non-gamers, novice and experienced AR users.

In summary, learning from our own design process, we updated the prototyping methods and process that fit well with the medium of HAR interfaces and improved the efficiency and effectiveness of prototyping.

Game Interface as Design Material

In the three game prototypes that my team and I designed, the game interface of HAR is one big source of our inspirations. I use the term affordance to describe the properties of the HAR interfaces as design material. Many of the game design choices were trying to take advantage of the affordances of HAR interfaces and design around their constraints.

The term "affordance" was coined by the perceptual psychologist Gibson to refer to the actionable properties between the world and an actor (Gibson, 1977; Gibson, 1986). Norman redefined it to be "the *perceived* and *actual* properties of the thing, primarily those fundamental properties that determine just how the things could possibly be used" (Norman, 1988). Affordance provides strong clues to the operations of things (Norman, 1988). In the later discussions and clarifications about the meaning of this term, Norman wrote that his focus is the "perceived" actions that are meaningful to a user (Norman, 2004). The question raised for the designer is to how to convey these actions and their meanings through the design.

Affordance is different from the inherent features of a medium. It lies in the relationship between the actor, the action, and the object. The new media of Augmented Reality has the following three features: blending the virtual and physical worlds, continuous and implicit user control of the point of view, and interactivity (MacIntyre et al., 2001). To turn these features into affordances in the game, our design has used metaphor, natural mapping, and constraints (Norman, 1988). For example, in the

NerdHerder game, we leveraged the metaphor of a fishing line and hook to imply the physics of the game control. When players see the rendered fishing rod, line and hook, they perceive that they can dangle the hook just as they could do in the real world. When their action produced the expected result, users establish the meaning of their actions.

In the multi-user scenarios, the interface of HAR can support users' "inter-referential awareness", which refers to "the ability for one participant to refer to a set of artifacts in the environment, and for that reference to be correctly interpreted by others." (Chastine, 2007). To turn this feature into affordance, we created motivations for players to talk about certain digital and physical objects as part of the gameplay. For example, in *AoD*, we designed the tangible game pieces that a player can pick up and place. Players used gestures, pointing at these physical pieces to assist their verbal communications about the collaborative actions.

Exploring and leveraging the affordance and constraints of reality-based interfaces requires both engineering and design efforts directed at turning the capabilities of HAR interfaces to the operations that the users can perceive and are motivated to try out. Each of the HAR technologies in the game prototypes, including predefined multi-marker tracking, dynamic multi-marker tracking, color and shape detection, and natural feature tracking, has their own capabilities and limits. The design choices we made carefully considered these features and turned them into affordances that players can perceive and "non-affordances" that indicate the limits and boundaries. The specific design choices are discussed in each chapter of the projects.

Theory-based Design

Theories in RtD research produce and support design practice in different forms: it can be design rationales based on a researcher's own conceptual statements, borrowed from existing research, or manifesto (Gaver, 2012). In my work, I borrow theories from sociology and adapt them to the domain of co-located gaming. I believe that these theories provide a useful initial framework to examine the complicated social play phenomena, and I therefore decompose them into elements and procedures that design elements can support.

Theory-based design has been adopted in the domains of game design and ubiquitous application design, and has proven to be fruitful. For example, to guide the design of game characters, Isbister leverages social psychology theories, such as social surface, empathy and emotional feedback, and body postures to explain why good game character examples connect better with players (Isbister, 2006). Zimmerman used product attachment theory to design applications that support users in transforming certain aspects of their life for the better (Zimmerman, 2009). Consolvo et al. borrowed behavior change theories and created theory-based guidelines for designing pervasive health applications (Consolvo et al., 2009). In these examples, researchers leveraged the application and rhetoric power of the theory (Halverson, 2002) to reveal the underlying conceptual constructs that make a design work, and to provide guidelines and implications for creating new applications.

In my work, I choose sociological theories that were developed for the user scenarios of small-scale co-located face-to-face interaction. Although these theories are "true" knowledge about human-human interaction, they were not created for understanding mediated interaction in gameplay scenarios. To adapt these theories to the domain of co-located gaming, I use them as a lens to analyze empirical data on co-located games. This data may or may not be explained by the theory. Some part of the theories need to be expanded and adjusted for the field of reality-based computing and co-located gaming. As an outcome, adapting these theories generates a list of design guidelines that can be applied to the design of co-located games.

In the design of multiplayer *NerdHerder*, a subset of guidelines was chosen and integrated in the prototype. The game *NerdHerder* is an embodiment of theory-based design guidelines tailored for a HAR game interface. The user study on *NerdHerder* shows the detailed and diverse player behaviors of interaction and communication. The data analysis focuses on finding what design elements triggered or supported the different behaviors. The design and user study on *NerdHerder* provides an example of how the theory-based guidelines can inform the design and their usefulness.

Empirical Data Collection and Analysis

Game researchers and HCI researchers have studied co-located social play in different games (Seif El-Nasr, 2010). However, with the new game interface of Handheld Augmented Reality, how people interact with each other during HAR games was previously unknown. My thesis work designs and performs user studies to collect and analyze the empirical data on how people play HAR games. The main goal of these user studies is to find out how player interaction and communication is connected with the game design elements and the affordances of HAR games.

I conducted four lab-based user studies; one on each of the three game prototypes that we made and one on board games. The data that I collect includes: 1) observation and videos of the gameplay, to capture interactive behaviors (such as verbal communication, body movement, and gestures); 2) interviews and surveys, to understand the subjective experience in detail; 3) a game log to record the game events that may consequentially trigger certain behaviors. These multiple sources of data triangulate each other and give a detailed and balanced picture of the social play from the perspective of a player (the participants) and an outsider (the researchers) (Cohen et al., 2007).

I choose lab-based user study because 1) it provides a consistent physical environment between different groups players. As HAR interfaces encourage physical movement, the setup of furniture and space may affect how people move. 2) We can setup multiple cameras at positions and angles that captures how people move and their facial expressions.

Lab-based user studies have constraints. The biggest one is the lack of the real-world physical and social context, such as home, or game arcade environments (Sall & Grinter, 2007). A second limit is that the time scope of the study. The lab-based user studies involve a few rounds of game sessions, which typically only last for 30 to 90 minutes. Due to these reasons, the lab-based user study is not an ideal fit for exploring research questions about the context of play or the long-term game experience. However, for the purpose of this research, which focuses on the inter-personal communication and interactions during the game, lab-based environments are in fact a good fit.

My user studies do not compare games with HAR interfaces with another interface by making the same game that use two kinds of interfaces. As the game interface is integral to the design product, I do not believe it is fair to compare a game designed with the HAR interface (which impacts design decisions in every phase of development) with the same game using a different interface, for the purpose of comparative study.

To collect and analyze empirical data of gameplay experience, this thesis adopted the following five research methods.

Observations

With the research focus on social play, the goal of the observations is to record and take notes about the social interaction during the gameplay. As Connelly and Clandinin (1990) highlight, all qualitative observational research involves formulating a thoughtful and well-understood relationship between the researcher and research participants (Connelly & Clandinin, 1990). My role is a non-obtrusive outsider that records noticeable events as they happen. It is important for the researcher to be present to experience the atmosphere and emotional experience themselves during the game.

The observation also provides opportunities for researchers to prepare some of the interview questions that are highly specific to this group and their dynamics. For example, if the group of players presented uncommon behaviors, the researcher can add a question in the interview about the thought process behind it.

Social behaviors are complicated and oftentimes entangled. Therefore I prepared a sheet beforehand to summarize the possible social interaction behaviors based on the two dimensions of "actions and reactions" (e.g., verbal communication, laughter, joking, gestures) and "the purpose of actions" (e.g., collaborative learning, to help teammate, to compete). This sheet is attached in Appendix A.

Video Analysis

Similar to observation, a video-based analysis method is a good tool for determining what happened during the interaction, especially for the fast, sub-conscious actions that players may not be aware of. Video recordings are seen as "microscope of interaction", and have been widely adopted in the research in sociology (Knoblauch et al., 2006). Compared to the naked eye, they are more detailed, accurate (Knoblauch et al., 2006), re-playable, and support collaborations among multiple researchers (Derry, 2007). Video analysis has been widely used in education and sociology research (Derry, 2007); it is a good fit for my research on inter-personal social play behaviors.

To turn video recordings into data, the first step is data selection, a process of focusing on particular information in accordance with the theoretical frameworks, research questions, and instruments (Derry, 2007). The purpose of video selection includes "*depicting or telling a narrative account of some phenomenon*", "*creating a source for information storage and retrieval that will support the identification and analysis of data*", or a combination of both (Derry, 2007). While in the *BragFish* and *AoD* study, video analysis were mostly used for its narrative power, selecting events that best illustrate the evolving interpretations of the data. The data analysis from these two user studies shows that the physical interaction (e.g., body movement and gestures) is a salient feature of the co-located gameplay of HAR games, which suggested a more systematic approach could be fruitful. In the studies on board games and *NerdHerder*, videos recordings become the main data sources. I systematically extracted the social interaction events and clustered them, to find the behavioral patterns. The events are time-stamped and transcribed, with special attention paid to the reasons or triggers for these events. If the game event is not observable from the video (e.g., there are game states that do not have particular sound effects), the game log data are later paired with the video to understand the reasons for the behaviors. This analysis ties the game design together with players' behaviors.

Game Logs

On small devices such as smart phones, it is hard to observe what is happening in the virtual game world through observation or video recording. Hence, game log data needs to be collected with timestamps to pair itself with other forms of data, such as video recordings.

In both the studies of *BragFish* and *NerdHerder*, the game events were recorded. In *AoD*, I did not log the gameplay data since the screen capture is recorded on video. Recorded game event logs are synchronized with the video recordings of the gameplay to explain which game events may trigger subsequent player actions and reactions. In the *NerdHerder* study, I also sampled and recorded the position of the cameras and in-game avatars. The game log can be used to explain players' interactions and change of emotions.

Interviews

The goal of interviews is not to prove or disprove hypothesis. Instead, "*at the root of in-depth interviewing is interest in understanding the lived experience of other people and the meaning they make of that experience*." (Seidman, 2006) While observations and video analysis is conducted from the perspective of the researcher, the interviews aim to obtain a “subjective understanding” from the perspective of the participants. Interviews are suitable for answering research questions about intentions and motivations, and the hidden internal cognitive processes. For example, one of the questions we constantly ask our participants is, “what is your strategy during the game?” The answer to this question may not be revealed in front of competitors and is best revealed during the interview.

The interviews that I conducted were semi-structured group interviews. Due to the fact all the games I study are multiplayer, group interviews are more feasible. Moreover, it may inspire discussions among players. The shortcoming of group discussion are that players’ answers are inevitably affected by others. Before the user studies, I prepare a list of questions for the interviews; the one that is used in *NerdHerder* study is included as an example (Appendix B). During the interview, new questions are raised based on participants’ answers and comments. The design of the interview questions are discussed in the next paragraph.

An in-depth interview include three components, including 1) focused life history, 2) the details of experience, and 3) reflection on the meaning (Seidman, 2006). The first component, focused life history, is to provide a context of player(s)’ previous relevant experience. In my user studies, the background information and players’ past game experience (especial with reality-based game interfaces) are surveyed in the demographics questionnaire (which will be introduced in the next section). During the interviews, I also asked players to compare their past co-located social game experience with the HAR game they just played during the study. For the second component, the details of experience, the interview questions ask about events in the game that may be memorable to the players. Some of these questions are generated from the observation of game sessions, from which the researcher generates questions specific to certain events (i.e., the burst of emotion among the groups). The researcher also asks about the strategies of gameplay, which may open up discussion among the players. The third component, reflection on the meaning, are mostly questions asked in following the participants own comments and reflections. For example, when a player said that she preferred collaborative games over competitive games, it was unclear what games she had in mind when drawing the conclusion, i.e. whether it was a statement about personal preference or a comment about the game she just played, and whether the social relationships among players could affect her preference. Hence, the meaning of players' comments often needed to be further examined.

Surveys

Surveys are tools that self-evaluate subjective feedback (Babbie, 1990). In my work, I use surveys for several purposes, including collecting players' demographics and previous game experience; understanding players' social presence with other players; and the overall game enjoyment. Here I introduce each of the goals and the corresponding survey instrument that I choose.

Player demographics, such as age, gender and culture, have a strong impact on the type of game a player would tend to enjoy (Schell, 2008). Beside basic demographic information, I also collect players' game-related experience, including their familiarity with reality-based game interfaces, past experience with AR, and what kind of gamer they see themselves as. This information is related to players' skills, learning, and competitiveness. Knowing a player's demographics and past game experience helps making sense of other data, e.g., player preference and performance.

Social presence is an important dimension of a social interaction experience. Social presence often refers to a communicator's sense of awareness of an interaction partner (Biocca et al., 2001; Short, 1976). I borrowed the social presence questionnaire from the literature (Biocca et al., 2003; De Kort & Ijsselsteijn, 2007) and adjusted the questions to be more relevant to the scenario of co-located social games. The social presence survey that I used in *NerdHerder* study is attached in Appendix C. It is composed of the questions regarding players' emotional and behavioral awareness with each other during the game, combining questions selected from the social presence surveys of Networked Minds Measure of Social Presence (Biocca et al., 2003) and Social Presence in Gaming Questionnaire (De Kort & Ijsselsteijn, 2007). The former focus on communication partners' awareness and attention distribution in both collocated and mediated interaction settings (Biocca et al., 2001). The latter evaluates three dimensions, psychological involvement (empathy and negative feelings) and behavioral engagement. In the study with the NerdHerder multiplayer game, I expanded the questions to accommodate the team-based competition structure, asking about the social presence with the player's teammate and the opposing team respectively.

When players finish a game, they walk away with a higher or lower sense of enjoyment. I use a self-measured game enjoyment survey to collect players' overall feedback on the game experience. It is different from the social presence survey, as higher-levels of social presence do not always lead to more enjoyment, as revealed in my BragFish study (Xu et al., 2008). In the game enjoyment questionnaire, I include questions about the usability, playability, and social play aspects of gameplay experience. This questionnaire's design is influenced by Game Experience Questionnaire (GEQ) by (IJsselsteijn et al., 2008), which is built on the Flow theory (Cowley et al., 2008). However, Flow theory was not created to understand inter-subjective behaviors, such as social play. Thus GEQ's usefulness in my work is limited, as I focus solely on social games. The questionnaire I used to measure game enjoyment is attached in Appendix D.

Research Outcomes and Evaluation

RtD research method produces design artifacts that integrate the "real", "true", and "how" knowledge and embody designers' understandings of current state (Zimmerman et al., 2007; Zimmerman et al., 2010). This thesis creates three Handheld Augmented Reality games, each of which cover different points in the design space made by different underlying technologies and the interactions, and by the different kinds of social dynamics created through the competitive, collaborative, and group-based competitive structures. The resulting artifacts can be seen as a proposition for a preferred state or as a placeholder that opens a new space for design, allowing other designers to make artifacts that then better define the relevant phenomena in the this space (Zimmerman et al., 2010).

Moreover, we conducted user studies on these games, collected and analyzed empirical data on how players interact with the game and with each other. The studies yield more “real” knowledge on social play behaviors during games with reality-based interfaces. One of the game prototypes we created, *NerdHerder*, is grounded in the sociological theories. Therefore, the user study findings on *NerdHerder* also show whether the theory-based design guidelines achieved the expected behavioral outcomes or not, and how game design could benefit from theories. This work is a case study of theory-based design. The design artifact can be profiled by its theoretical roots (Gaver, 2012).

Through designing and studying multiple HAR game prototypes, we followed the iterative design process and created the loop between technology and people – it is neither the innate feature of HAR interfaces or players’ co-location that guarantee the social play. Social play is encouraged and supported through the careful design that matches the affordances of HAR interfaces with the human process of joining attention and elevating social interaction experience.

Although it is still debated how the quality of RtD workis measured, Zimmerman et al. brought forward a set of criteria—“*Process, Invention, Relevance, Extensibility*” (Zimmerman et al., 2007). “Process” examines the rigor applied to the selection of methods and the detailed documentation of design and research process. In this thesis, I document the design process and rationale in great detail, so that fellow researchers could understand why the design prototypes were shaped in certain ways. “Invention” requires interaction designers to prove that they have produced novel integration of various subject matters to address a specific situation. The prototypes designed in this thesis are in a relatively novel space where not many successful previous examples can be found. “Relevance” is considered to be the benchmark for RtD research. This is to replace the criteria of “validity”, which is required in scientific and behavioral research. In this thesis, the focus is on one kind of reality-based interfaces, handheld augmented reality, which provides a case study that probes into the larger space of social games that leverage the hybrid co-location of players.

CHAPTER 4

BRAGFISH—EXPLORING SOCIAL PLAY THROUGH DESIGN

The first research question is to understand "What kind of co-located social play behaviors and experiences are supported by HAR interfaces." There were few multiplayer Handheld Augmented Reality games that we could study and collect empirical data with back in 2007. Therefore, as one of the initial efforts to answer RQ1, I worked with a team to design and develop a Handheld Augmented Reality game. The design rationales of the game came from 1) our knowledge and experience with the state-of-art HAR technology at that time; 2) the goal of encouraging social play by the affordances of HAR interfaces. While many previous AR games were used as a testing vehicle for new technologies, we designed the game first and foremost to create enjoyable and social experience.

In this chapter, I first present the design rationales, process and product of *BragFish*, and then report the user study method and the main findings. *BragFish* user study answers questions about how different channels of communication support the social presence between players, and how the registration between digital and physical objects affect social presence. The empirical data shows how competitive players observe and interpret other's physical actions and verbal communication in the game.

Introduction to BragFish

BragFish is a multiplayer tabletop handheld Augmented Reality game designed for players to play games around a shared physical space using their handheld devices (See Figure 9). This experience leverages hybrid features from both handheld video games and board games, and aims to foster social play among friends and families. In addition to trying to create a fun game, we use *BragFish* as a research tool to explore the relationship between the distinctive characteristics of handheld AR technology, specific aspects of the game's design, and the resulting social play. We are particularly interested in identifying what factors affect the emergent social interaction triggered by the affordances of handheld AR interfaces.

Figure 9. (Left). Three players playing BragFish; (Right). A screenshot during the game.

BragFish is played on a physical game board with several handheld devices, each of which has a camera mounted on the back. The board is covered with a regular grid of fiducials (See Figure 9). The core game mechanic involves the players navigating their boats around a lake, casting their lines, reeling them back in, dumping fish onto the dock and ramming other players' boats to steal their fish. The players look at the game board through the device screen and control their boats using the device's buttons. Casting of the hook and lure (referred to from here on simply as "the bobber") is controlled by pointing the crosshair that is fixed in the center of the screen at the target location on the map. The virtual boats and fish, water and effects are rendered on top of live video streaming in through each player's camera. There is a radius around the boat where the player can see fish. A boat has three kinds of skills: ramming, defending and fishing. All of the skills increase when corresponding action is performed, and decay at a fixed rate. Ramming skill decides the probability of stealing a fish from the rammed boat. When the ramming skill goes up to a certain level, the player will become a pirate, with an icon shown on top of the boat. When fishing skill goes up, the range of fish that can be seen from a boat is increased, and a fisherman icon is rendered on the boat after fishing skill reaches a threshold value.

Game Design Rationales

Lessons from the Eye of Judgment

To help us raise research questions and refine methods for later user studies for *BragFish*, we performed an informal evaluation of the then-new PS3 game *Eye of Judgment (EoJ)* by observing several rounds of play with different players and asking them for feedback. Just as with *BragFish*, in *EoJ* AR technology appears to be one of the major inspirations for the game design, attempting to leverage the affordances of this interaction paradigm. The goal of our evaluation was to identify both the effective and ineffective game mechanisms in this first commercial AR game.

In *EoJ*, the use of the camera to view the cards enables the seamless and automatic score keeping and rule enforcement that often motivates computer implementations of card games (e.g., there are many computer programs to automate rules and combat in role playing and tabletop real-time simulation games). However, one big issue with this game is that the graphics and "AR" added little to the game beyond pleasing "eye candy;" the game could be played as a card game without the PS3 and/or without AR. In the game, the AR technology functions as an enticement and reward for players using the system, rather than as an integral part of the game. In our view, it is unlikely that once the novelty wears off, this added value will entice players to continue playing what amounts to a fairly basic card game under a camera, in front of a TV. In contrast, our design of *BragFish* takes advantage of AR technology by exploiting the shared physical space, and embedding it into the design of game mechanism.

Encouraging Social Interaction

Having networked devices and co-located players does not guarantee that social interaction is increased, which has been found in the literature (Szentgyorgyi et al., 2008). Although the Gizmondo device shares a similar form factors with the Nintendo DS, the use of AR to overlay the digital game space on a physical game board introduces a shared space among players. All players are aware that they share a one-to-one mapping between the physical space and the digital game space, which builds a common ground for social interaction that guarantees common interpretation of the physical actions of players in the game space (i.e., supports inter-referential awareness (Chastine, 2007)).

We design the game mechanics to encourage social interaction, including mechanisms to intensify the conflict between multiple players and to introduce social roles. Beyond simply competing for a limited fish supply, the boats have the ability to ram into each other, and steal fish from each other. When successful, the rammer's ramming skill will increase, which means that she has a better chance of stealing a fish from others in the future; at the same time, the ramee's defending skill is increased, making it is less likely they will lose a fish next time they are rammed. By balancing the game in this way, we enable players to adopt different roles according to the strategy that they prefer: more aggressive play will lead to the role of a pirate, while players who are more interested in fishing will become a fisherman.

Leveraging Players' Physical Movements

The interface for *BragFish* is designed to provide transparency of player actions to opponents via physical movements in order to encourage players to interact and observe each other in the hybrid physical-digital space. Keypad buttons control boat movements. Players cast by centering their camera (indicated by a crosshair in a translucent circle in the middle of the screen) on the desired location in the lake and pressing a button. After the cast, the bobber will be positioned at that location in the lake.

The player can then reel the line back in by holding down a button on the keypad. If a fish “nibbles” the line the device vibrates and the player must hit a button immediately to reel it in.

Each of these player actions is discernible at many levels. If a player is pointing the device at the game board and looking at the screen it is clear that she is actively seeking fish while a player that is simply holding the device in her hand (and perhaps glancing at it) may be waiting for a fish to strike or taking a break from playing. If a player is actively participating, even casual observation reveals what action she is taking (as the movements for navigating the boat, casting, and reeling in a fish are quite different) and the position and orientation of her device indicates where the actions are taking place.

Just as with actual fishing it is very obvious when an opponent hooks and catches a fish. When a fish “nibbles” an opponent’s line the player will observe (via sound and visuals) the opponent’s device vibrating followed by the opponent locating the appropriate button and pressing it to catch the fish. These sudden rapid movements by a player are an indication that she is finding success in the game, contributing to the feeling of excitement and urgency in the group.

Maintaining Awareness of Game State

BragFish uses visual and aural feedback, along with haptic feedback (i.e. the device vibration) to convey game state to the players. The goal is to take advantage of the affordances of AR while supporting casual unfocused play. Therefore information that is only of interest to an active player is registered with the virtual scene (e.g. boat and fish locations). Information that would be used by a player to maintain awareness of state (e.g. whether a fish is on the line, or how many fish you have caught) is presented either as haptic information or as audio feedback, allowing a casual player to continue social interactions while still participating.

The most important feedback to the player is the status of her line. This information is conveyed haptically so that a player can monitor her line without having to look at the device and without having to actively engage in the AR component of the game. If a fish "nibbles" the hook there is an initial short vibration to indicate to the player that there is an opportunity to catch a fish. The player must then immediately push a button to actually catch the fish.

The auditory and haptic feedback received by a player is discernable by other players if they are paying attention. This serves to increase the tension in the game, as the relative success of the players is made clear to the other players. The players are also able to check on the number, size, and type of fish the she has caught by hovering the crosshair over the dock and other boats. This information is viewed as a standard 2D display on the device.

Another important aspect of game state is to indicate and recover from the technology breaks, in particular losing AR tracking of the game board during the game play. When the tracking is not working, two red bars are shown on the sides of the screen, and the crosshair will spin. Users can adjust their movements or positions after seeing these signs.

Implementation

Bragfish was developed for the Gizmondo handheld gaming device. The Gizmondo has a 2.8-inch LCD screen with a 320x240 resolution and a rear-facing camera. The device runs Windows CE, and the application was written in C++. Bragfish uses the StbTracker computer vision library for marker detection and pose estimation. It also uses Mobex3D, a 3d graphics framework designed for handhelds.

BragFish supports up to three players, with networked play carried out wirelessly over Bluetooth. One device is used as the game host and acts as both server and client, while the other devices ask to join this hosted game. The server broadcasts messages to the client devices while the clients communicate directly with the server. The messages passed between server and clients include fish catching requests and acknowledgments, position updates, and collision notifications.

Bragfish is played on top of a custom 31-inch square board with an image of a beach island. Overlaid on this image is a 4x4 grid of StbTracker "frame markers" which the Gizmondo uses for tracking. Images are captured using the built-in camera and passed to StbTracker, which calculates and returns the transformations required for Mobex3D to align the virtual world with the real world. The camera images are also copied into texture memory to be rendered along with the virtual world so that real world entities are included in the final image. On average, the game runs at a frame rate of 15 frames per second.

User Study

The purpose of the user study is to understand how the AR technology affects the game experience, especially the shared physical/virtual space. In this study, we try to begin to answer the research questions posed in the introduction.

Participants, Setting and Procedure

We recruited 9 groups of participants on a university campus. Each of the groups had 2 players. 7 of the groups were made of friends, while 2 of the groups were made up of strangers. The average age of the players was 24.5. Five of the participants were female. 9 participants categorized themselves as "casual" players, 5 as "hard-core" gamers, 4 as "cool player"(according to Electronic Art standard, mentioned in (Bateman & Boon, 2006)). According to Bartle's research about player roles in multiplayer games (Bartle, 1996), two participants reported that they are "achievers," 8 are "explorers," 5 are "socializers," and 3 are "killers."

The “game space” for this study was situated in our research lab. The space was configured to provide a comfortable gaming and relaxing environment. Food and drinks were provided to the participants before and after the user study. We tested 3 configurations of the play space to determine how different communication channels affect the play experience (see Figure 10). The first was the “shared board” (ShB) mode in which two players played with the same marker board; the second was the “separate board” (SepB) mode in which two players each had their own board (they were still able to see and hear each other though); the third mode was “separate space” (SS), which was similar to the second mode except that the two players are separated by a white board between them (and although they could not see each other, they could still hear each other). The communication channels available in each mode are shown in Table 1. The experiment was configured as a within-subjects user study – each of the groups experienced all three modes, and they played three rounds under each mode. To balance the order effect, we changed the play order of different groups according to a 3-by- 3 Latin Square. During the game, the players were free to sit, stand or move as they pleased.

The design of our user study was inspired by Henrysson et al.'s work on evaluating AR Tennis (Henrysson et al., 2005) in the sense that we also set up different testing conditions. However, our research method focused more on qualitative data collection and analysis, aiming to answer the research questions of identifying the factors that may make a difference in social play experience of handheld AR games.

Table 3: Three different modes and the communication channels provided by each configuration

mode ShB: Shared Board	In game, aural, visual and physical cues
mode SepB: Separate Board	In game, aural and visual cues
mode SS: Separate Space	In game, audio cues

Figure 10. Three settings in the user study: (left). Shared board mode (ShB); (middle) Separate board (still can see each other) (SepB); (right) Space separated by whiteboard (can still hear each other) (SS)

Both qualitative and quantitative data was collected. During the game play, events such as fish catching, ramming and status checking were logged. The game sessions were taped and a researcher took observation notes throughout. At the end of the user study, the players answered a questionnaire to give general ratings for the game design and to compare the social presence of the three modes (See Table 4). In the end, a semi-structured interview was conducted.

Table 4: Questions for comparing social presence in different modes

1	How much social interaction is involved in your game play?
2	How aware are you of what's going on for the other player(s)?
3	How aware are you that you are being observed by the other players(s) during the play?
4	How much is your play action influenced by the action of the other player(s)? (*note: the actions include: physical movement, dialogs, or actions in the game world*)

We are aware that the setting for a controlled experiment such as this one cannot reflect how this game would be played under different social contexts, such as at home, in bars or in the lunch room. Therefore, this study cannot fully reveal how the game and resulting social interactions would be affected in those environments. These reservations notwithstanding, such studies are useful as they allow us to collect detailed qualitative and quantitative data, which can yield insights not possible through more informal longitudinal studies.

Main Findings

Overall feedback about the game and its interface

The game received positive feedback overall. The following table lists the self-reported results of some dimensions, on a 1 to 7 Likert scale (higher scores implies more positive experience).

Table 5: Feedback about the game

	Mean	Std
Enjoyment	5.71 out of 7	1.359
Engagement	5.50 out of 7	0.985
Ease of learning	5.20 out of 7	1.673

Participants showed a common preference of playing with a human opponent rather than a computer-controlled one (mean=2.15/5, lower scores mean that participants are less likely to prefer to play with a computer). This result corresponds with Ravaja et al.'s similar findings using Game Boy Advance (Ravaja et al., 2006). Several participants also mentioned in the interview that, they preferred to play this game with friends or family, rather than people they didn't know before.

We observed different game play experiences among the participant groups. Three of the nine groups exhibited a strong social flow between players, which was evidenced by the dramatic emotional cues observed in the players (e.g. gestures, outbursts, excited conversation (Isbister & Schaffer)). Three of the groups showed a medium level of social flow, yet the interaction level inside the game was still high, as evidenced by the amount of ramming and status checking recorded in the log data. Three of the groups showed a low level of social interaction, both inside and outside the game. So far we cannot tell whether the player experience is related to pre-existing social relationships or gender norms, because the current data only has two groups of female players, one male- female pair, and only two groups where participants were not friends prior to the experiment. In the future study, it will be interesting to find how the pre-existing relationships and social norms can influence the social play in handheld AR games.

From players' self-reported rating, we found that they thought that this AR game interface was intuitive to use (avg=3.42/5, std=1.017); and it provided enough feedback during the game play (avg=3.53/5, std=.943).

We identified an ergonomics issue related to the top down view that the game interface requires, in order to provide optimal tracking of the markers on the game board. Using the handheld device was not comfortable for long play sessions, and many players complained that the game required them to "bend too much" (P14) and they prefer to "sit back on the couch" (P10). Two groups of players alleviated this problem in the SepB mode by tilting their coffee tables to be closer to vertical (see Figure 11).

We originally felt that fishing as an activity lent itself to a handheld AR game implementation due to the fact that, even in real life, this is a slow paced social activity with competitive overtones. However, during the *BragFish* game play, we observed the game became fiercely competitive and attention-demanding under the lab setting. As put by P2, *"(when the tracking is not working) It seemed to get in the way at the worst time. When I see a fish, I get excited and try to position the camera quickly – this caused tracking problem, though*."

Figure 11. Players reconfiguring the game space to get a more comfortable position of play.

Emergent and Embodied Play

Through our observation, interviews and recorded video, we found that players are creatively leveraging the social/physical context and integrating them into their own play approaches, especially under the mode of shared board. The examples are as follows:

- P11 reported how he anticipated the other player's actions in the game by observing his physical movement in ShB mode. In this case, zooming out (pulling the device away from the table) and panning the device meant the other player was preparing to ram or check the other player scores; while zooming in meant he was trying to catch a fish.
- P9 positioned her device on top of P10's device to physically block her view of the screen (see Figure 12, gameplay in ShB mode). This action happened when these two players move close to each other. The separate devices and shared physical space lead to this interesting play behavior.

Figure 12. A player moving her device underneath her opponents' screen to block her view of the board.

- P3 reported that his strategy was to intentionally stand in the way of the other player (in ShB mode). He believed that the other player could not get a good position for tracking or zooming in on the board and thus he could not effectively fish.
- P16 turned the game into a fierce action game. He stalked the other's boat, and whenever he heard the fish-catching sound from the opponent's device, he rammed his boat, attempting to steal fish (this happens in both ShB and SepB modes).

The above cases are not an exhaustive list of the creative game strategies employed by the players. The richness of their interactions showed that the players rapidly adapted and immersed themselves in the gaming sphere by receiving and interpreting visual, aural, physical, and virtual cues in their own ways. The potential for such embodied and emergent interaction sets handheld AR gaming experiences apart from many other handheld games, console games and board games. When asked to compare their *BragFish* play experience with other game experiences, four groups of the players talked about how *BragFish* is similar to the *Nintendo Wii* (the game title of *SmashBros* was mentioned three times), both of which involve more physical and social interaction than traditional games. Interestingly, one of the players described *the Eye of Judgment* experience as different from BragFish, although both of them are based on AR technology.

Multi-channel Interaction

The purpose of the three modes was to isolate and identify which components of the communication channel matters most. Below are the hypotheses and results:

Hypothesis 1: There is no significant difference between social presence levels in the three modes.

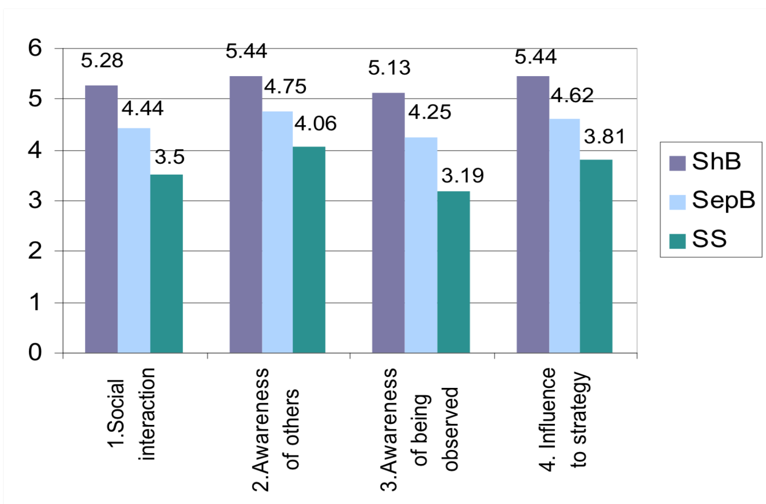


Figure 13. Average ratings for the social presence questions (in a 1-7 Likert scale, 1= least, 7=most)

From the study, we found that there is statistically significant difference between all three modes for each of the social presence questions listed in Table 2, except that there is no significant difference between SepB and SS mode for question 2: Awareness of the other player (t-test, t=1.84, p=0.085). The average ratings of the social presence questions (on a 1-7 Likert scale) are listed in Figure 13.

Hypothesis 2: There is no significant difference between the players' enjoyment of the three modes.

There is no significant difference of enjoyment between the ShB mode and SepB mode (t-test, t=0.76, p=0.45), although a majority of participants (11 people) liked ShB most (6 other players liked SepB most). There is significant difference of enjoyment between the ShB and SS modes (t-test, t=2.78, p=0.015). Moreover, in SS mode, the frequency of verbal communication and self-reported social interaction level is reduced significantly as well (t-test, t=3.50, p=0.003). This result shows that when players cannot see each other, the channel of visual cues is lost and the social interaction diminishes instead of being sustained by an increase in verbal communication.

It is interesting to explore how social presence influences the game experience. One might assume that the higher the social presence is, the more enjoyable the game is. Instead, we found that this is not always true (as shown by the combination of results from hypothesis 1 and 2). An easy conclusion is that visual cues are playing an irreplaceable role in the social play experience, as described by P2, "*out of sight, out of mind*". But a closer look at the qualitative data reveals instead that each of the three experimental modes has its own affordances that, if designed properly, are appropriate depending on context and player type. The following section discusses the issues inherent to each mode and the resulting design considerations.

<u>Space management</u>

In this context the term "space" means both virtual and real space. In some cases, players reported that with shared board and AR, they can align the real world movements of the other player with the movement in the virtual world more easily and directly (P4, P9 and 10, P11, P16); also, some players reported that they would prefer to stay in their social comfort zone in both virtual and real space (P5, P6, P8). Below is the quote from P5, Group 3 (a group made of two strangers): "*I rammed him once at the beginning, but* *he did not ram me back, so I stopped…I guess I need to be polite... I just stayed on my side and carried on fishing…*" This is one example of how social norms can override game play strategy. It also reveals that, when designing multiplayer handheld games, social interactions can not be "forced" as players may prefer to remain in the private gaming sphere of their own device.

Exposure of technology

Using the shared board gives players the possibility of interfering with the other's game play by leveraging the technology (and capitalizing on its limitations). Some social groups might deem it inappropriate to impede the other player's game play via physical contact, but it is also easy and fun to manipulate the shared space to the same ends. As mentioned in above section, P10 tried to block P11's view on the screen by putting her Gizmondo on top of the other one, and P3 tried to occupy better physical position for tracking. Both of these examples showed that players are strategically embedding their understanding about how system works into the game play. However, the limits and seams of the technology are equally exposed to both players.

Emotional intensity

Although the proximity between players was approximately constant in each mode, the shared board mode resulted in a stronger self-report of "being together" than the other two modes (ShB vs. SS, t-test, $t=3.12$, $p=.003$; ShB vs. SepB, t-test, $t=2.57$, $p=0.012$), which was accompanied with the increased numbers of emotional bursts seen in the video.

Interestingly, we found two groups (group 2 and 8) in which both players had a stronger sense of "being together" under shared board mode, despite the difference in mode preference: one player prefers shared board (ShB), while the other prefers separate board (SepB). Below is the quote from Group 2.

P3: "*I like the shared board best. I just like it because I know where he is looking… I will assume generally where he is looking, and I am going to bother him along.*"

P4: "*I like the separate but close. Everyone has their own (board that they can work on their own). You don't have to worry about bumping elbows with anybody." P3: "I like it though; I can get to your way*" (laughed)

P4: *"(That was a) Distraction~"* (both laughed)

This example shows that a stronger sense of "being together" leads to more intense emotional experiences, which could be more exiting or more frustrating for different players. When designing games with shared physical spaces, we need to take the emotional reinforcement into consideration, so that the negative emotions, such as feeling more vulnerable and losing control, do not overwhelm the players.

Summary

Through designing and evaluating the game prototype of *BragFish*, I aim to understand how the "shared hybrid space" enabled by HAR technology affects social play experience, including the social presence and social interaction. The prototype was designed to encourage certain behaviors, such as the social interaction, physical movements, and awareness of the game state. Through the user study, I found that players constantly monitored and also signaled to each other about the game state by their body movement and verbal communication, which effectively connected the physical and digital worlds. The findings in the user study with *Bragfish* yield qualitative and quantitative data to answer research question 1 about the social behaviors during HAR games.

CHAPTER 5

ART OF DEFENSE—TANGIBLE INTERACTION IN HAR GAMES

With the development of HAR technology, it enables new ways for users to interact with the game world naturally and intuitively. Tangible interfaces (Ishii & Ullmer, 1993b) support users to use the manipulation on physical objects to control the digital objects. *ARt of Defense (AoD)* was created to explore what tangible interaction can bring into the social play in HAR games. I worked with a team of designers and programmers, designed and iterated the tangible game pieces that players can grab, place, move, rotate, and point to. During the collaborative *ARt of Defense* gameplay, players communicate with each other by leveraging the tangible game pieces.

Similar to *BragFish*, *ARt of Defense* was also created to understand the diversity of social play behaviors in HAR games (to answer RQ1). This chapter first discusses the design rationales and iterations for *AoD,* and then reports the findings from our user study with this game.

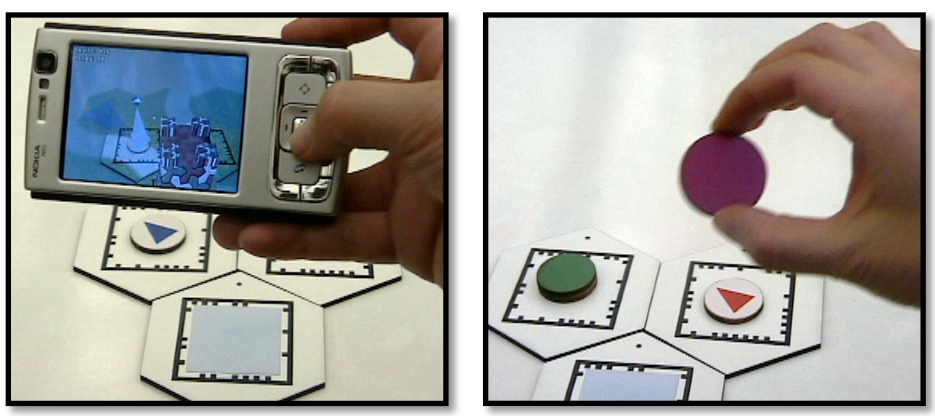


Figure 14. A screenshot of *AoD* – the camera phone is looking at a board built by hexagonal marker tiles. The tower is rendered on the tile using a blue color. The defense building is launched by the tokens. (Right). The power-up tokens used in the game.

Introduction to ARt of Defense

ARt of Defense is a networked two player cooperative game inspired by the "Tower Defense" genre. The objective of the game is to survive as many waves of enemies as possible by preventing them from reaching the base (see Figure 14).

Enemies approach along predefined paths that converge at the base and deal damage proportional to their strength. The game increases in difficulty with the enemies making more damage per unit. The game ends when the health of the base tower falls to zero. Players begin with a common pool of money that can be used to create new towers or upgrade existing ones. These towers attack enemies and earn money for each killed enemy unit. Players start with a single hexagonal tile (corresponding to the base) placed on the table. No tokens may be placed on this tile. There are 15 map tiles excluding the base (much fewer than the entire 10×11 game map). The map can be explored by placing additional tiles adjacent to existing ones (and adding them by viewing both tiles through the phone). Adding a new tile reveals the map corresponding to that region (including enemy units) and also shows the terrain in the neighboring tiles. Tiles can be removed and reused (towers can only be created on tiles that are in place in the world). Each player is assigned a unique color (either red or blue) that remains constant throughout the course of the game. The red player can only build red towers, which in turn can only damage the red enemies. Similarly, the blue player is restricted to blue towers, which solely attack blue enemies. Towers can be built on empty tiles on the map by placing a triangle token of the appropriate color and turning it to point the tip in the desired direction of fire. The player adds the tower to the game by viewing the tile through the phone and pressing a button. Each tower costs a fixed amount to construct but can be rotated at any time for no cost. There are three upgrade tokens (magenta, green and black) corresponding to an increase in the damage dealt to a unit, rate of fire and range, respectively. Each may be applied up to a maximum of three times per tower. To upgrade a tower, the player must place the token on the tile containing the tower and confirm the action on the phone. The final score is based on the time since the start of the game that the base tower has remained standing.

Game Design Rationales

Tangible Interaction

Picking the strategy genre allowed us to incorporate elements from board games (map building using hexagonal tiles, tangible game tokens) and their computer counterparts (limited visibility due to fog of war, real-time unit movement). Tower defense games typically need little to no micromanagement of player units, with the main player actions being the placement of towers (which automatically fire at enemies without player intervention) and upgrading of towers. Further, the pace of such games is moderate and does not require rapid button presses (clumsy on most mobile devices) or violent camera movements (disruptive for vision based tracking). Combining the gameplay of tower defense with the exploration aspect of other real-time strategy games (such as Blizzard Entertainment's Starcraft and Microsoft's Age of Empires) aligned perfectly with our vision of the player interacting with game pieces to deploy units and to also develop an understanding of a larger space than could be seen on the phone screen at a single instant of time.

Marker tiles for map building

We opted to embed a hollow square marker in a hex game tile for several reasons. The shape permits the addition of tiles in six directions and avoids the ambiguity of diagonal movement that is commonly seen in games using square tiles. Furthermore, the distance covered is equal in all six directions. Finally, we found it easier to handle hex tiles than square ones because they could be gripped without obscuring the marker. We used a laser cutter to fashion a set of hex tiles and soon discovered that this shape had the added benefit of better inter-tile alignment and led to more stable tracking because pieces were less likely to move during gameplay. We experimented with different sizes for the tile such that the inner space was large enough to permit sketching without the user accidentally crossing the boundary. We finally settled on a hollow marker with a size of 5.5cm, with each side of the hexagon being 4.85cm.

Tokens for tower building and power up

We looked to board games for inspiration. Physical pieces are appealing because they lower the learning curve for the player and create a mapping from the physical to virtual world. Further, the detection algorithm for sketching could be reused for these pieces, without many of the problems created by hand-drawn sketches. For the current game, we use exactly one kind of player unit: a directional tower that is represented by a triangle. Players could rotate the piece and look at it through the phone to have it shoot in the desired direction. While a more elaborate game could easily use more types of tokens, we wanted to refine the interactions and keep the game relatively simple to avoid overwhelming the casual player.

The decision to use tokens was made after we playtested an earlier version of the prototype where players created towers by drawing on tiles. With shape and color recognition technology, a player can draw the shape of the tower that has specific kind of strength they needed (e.g., fire faster, bigger attack range). However, we found that the interaction of sketching usually require both hands, which is inconvenient given that players needed to hold the phone in one hand already. Although sketches gave players more control of tower building, we did not find it with the constraints of HAR interfaces. Instead, we use the pre-made tokens that only require one hand to interact with, e.g., placing and rotating. And we created power up tokens to give special capabilities to the defense towers.

Collaborative play

One of our goals for *AoD* was to create a collaborative experience and test our intuitions about how AR would foster social interaction. Redesigning a primarily single player game concept (tower defense) into a cooperative game that fostered the desired interactions required more than just making the game harder. We considered several ways of dividing responsibilities amongst the players to encourage cooperation (for instance, one option was to allow one of the players to observe and explore the map while the other added towers), but we found such unequal divisions of labor to be disruptive to the player experience and to the balance of the game. Instead, we decided to allow both players to explore the map but each to only add towers of a certain color. To reinforce collaboration, we created two kinds of enemies that can only be destroyed by a certain color of tower. Towers of one color (e.g., blue) could inflict damage on enemies of the same color, but not on other (e.g., red). This helped us to avoid the scenario where players would split up the space physically and focus solely on their halves. Furthermore, the pool of money was shared between the players, forcing them to make strategic decisions together. An advantage of this color-based division was that it allowed us to design levels that could test the extent of cooperation between the players by varying the proportion of red and blue enemies in each wave. For example, if players did not communicate with each other, a path that was poorly guarded against blue enemies could be easily overrun. All of the above three game mechanics we used in our design, shared goal, complementarity, and shared resources are mentioned in the literature that research cooperative play (J. B. Rocha, 2008; Seif El-Nasr, 2010).

User Study

To understand the play experience and improve the game design, we conducted a small user study with twelve participants. Specifically, we hoped to understand how the augmented reality interface affected game play, and the kinds of cooperative play that occurred. These research questions were not merely designed to gather the feedback to improve *AoD*. Rather, we were interested in finding the patterns of behavior related to game interface and cooperative game design to inform the design of future handheld AR games.

Participants

We recruited twelve participants on campus. We recruited each person separately and ensured that each pair of participants were not friends before the study. All of the participants were undergraduate and graduate students from the computer science and computational media majors, aged 21-26. Two of them were female. The participants were from six different countries. Six participants did not have English as their first language. All but two had not played augmented reality games before the user study. All but two had the experience of playing with strangers in online games or sports. In the following sections, the participants are referred to using a convention like G1-A (the number is the group id, and the letter is the player id in the group.)

Procedure and Setting

The user study included three parts. First, the players learned the game interface. The participants were given a phone and game pieces, without the game running. A researcher gave an introduction to the game controls by following a pre-written script and showing a pre-recorded instructional video. Second, the participants played the game together. Each team was given at most three times to play. The video of the game sessions and player behavior was recorded. One observer took notes while the game was played. Third, the participants filled out the questionnaire independently after playing the game. Afterwards, a semi-structured interview was conducted to understand more about the incentives and experience. The user study was set up in a research lab. The two players sat on each side of the table, facing each other. The physical game tokens and tiles were piled at one end of the table. An instruction sheet showing how to use the phone buttons was provided to each player, for reference. To capture and synchronize the video of play behavior and game events, we recorded the game screens and top- down video for both players using a video quadbox (see Figure 15).

Data Collection

<u>Recorded Video and Observation</u>

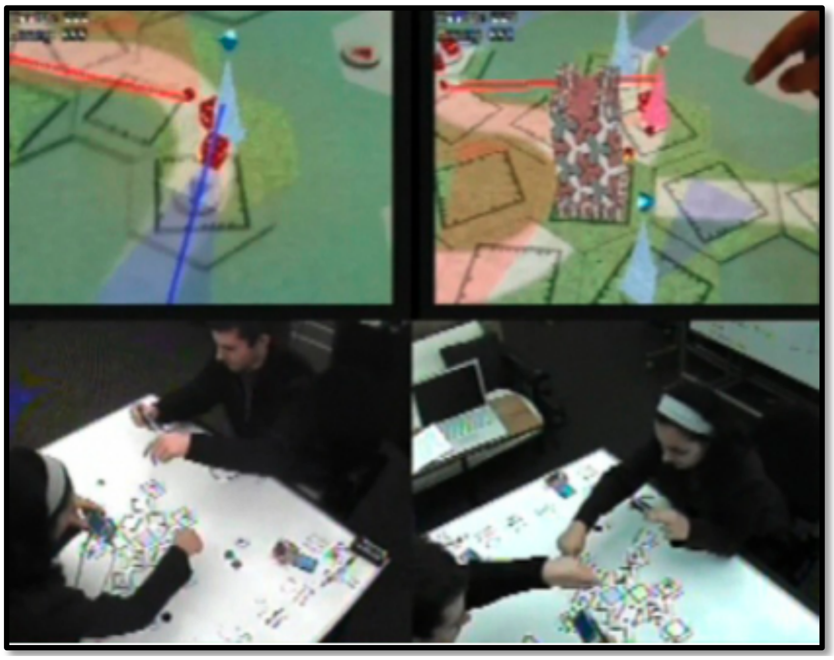


Figure 15. One scene during the gameplay of ARt of Defense. Mobile phone screens are captured in real-time, together with real world gameplay.

The recorded video synchronized the game screens with the top-down videos that captured the physical movements of both players. The cameras are tilted with a 45-degree angle to capture both the hand movements and the facial expressions. As shown in Figure 15, the top images are the real-time screen videos, while the bottom images are the camera recordings of players' action. With this data, we were able to reconstruct what went on during game play, how the players moved and the game events they went through. In addition, one researcher took observation notes during the game play, to record interesting moments of play and to generate related questions for the interview.

Questionnaire

The questionnaire was designed based on previous studies (e.g., (Mandryk & Maranan; Xu et al.)), and was divided into three sections: feedback about the game in general, evaluation of the game interface, and feedback about social interaction. We used cross-checking questions to address the problem of misreporting.

Interview

At the end of the user study, we conducted a semi-structured interview. While the observation and video focused on finding the behavioral patterns, the interview focused on understanding the subjective experience of the players, including the strategies they adopted, their awareness of the other player, and the comparison between this game and other games they had played before.

Findings and Discussion

User's Overall Feedback About The Game

Through the user study, the participants gave highly positive feedback about AoD (see Figure 16). We interviewed the participants about what they liked and disliked about the game. "Cooperative play", "Tangible interface", and "Game concept" were most frequently mentioned as pros of the game. "The graphics went off when I moved my phone" (registration problem), "blocking the other one's view", "need a better overview of the bigger world" were most frequently mentioned as cons.

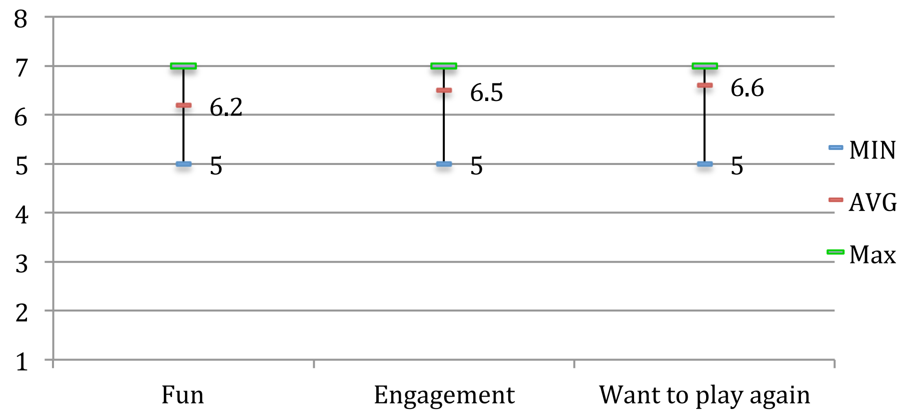


Figure 16. Feedback about game experience with AoD

Feedback About the AR Interface

Interestingly, the handheld AR interface is related to both what the participants liked and disliked, as mentioned above. While people agree that the interface brings more fun to the game (4.3/5), the score for “the interface gave enough feedback” is just a little bit above neutral (3.3/5). Below are some more specific observations. Handheld AR interface as the lens to the hybrid world: The handheld AR interface works like a lens onto the merged physical- digital game world. Like many games that have a fog-of-war effect, the players cannot see further than the spaces nearby. In AoD, the players need to physically move to explore the game space. Social interaction and collaboration is encouraged because of this, as discussed in the next section. However, this limited view also introduces some problems. For example, many players want to have a better sense of what is happening on the rest of the map. The lack of information about the enemy attack makes the game “hard to plan ahead” (G3-A, G2-B, G5-B).

Another issue is occlusion, meaning that the handheld is “blocking the way of the other player”. The players worked out their own ways around this issue after they realized it would be a problem. They either reached out to point to the marker from another direction, or waited for the other person to finish the action first. Interestingly, in our previous study of Bragfish, we found that players intentionally blocked the way of each other to occupy the better position in the competitive play. In both cases, the players understand how the interface works. However, the design needs to consider these kinds of space-related interactions.

Emergent play

Trust, reference and communication

We found that the three teams (G1, G3, G4) who got the highest scores shared a similar kind of strategy. One player would be in charge of two of the paths (there were four paths in the game level we used), and guide the other player to the location where they need to perform an action. Through observation and recorded video, we found that this process could be broken down into three major components: trust, reference and communication. All of these are closely related to the design of the interface. When players were using the handheld interface as a lens onto the game world, the limited area shown on the screen significantly affected game play. The strategy of moving around the whole map and making sure there are enough towers in the right places is inefficient with this limited view.

The players who got higher average scores realized that they could rely on the other player to cover half of the map and pay attention to only those places indicated by the other player. These groups mentioned that they needed to trust each other to make this strategy work (G1, G3, G4). As mentioned by G4, the immediate feedback assured by face-to-face interaction was necessary for creating trust between players who did not know each other.

Reference to Physical-Digital Objects

In this game, how to refer to a specific physical-digital object on the board became a key element for the collaborative process. One group found it hard to develop a successful reference protocol in the game (G6), while most other groups used pointing gestures assisted with deixis (i.e., "*this*" and "*that*") (G1-G5). Two groups also used physical tokens that they would place at specific locations to refer to later (G3, G4). The two basic protocols: pointing (directing-to) and placing (placing-for) can efficiently draw the attention of the other player. The tangible pieces facilitate using physical space as a reference system, and become an efficient form of communication mediation.

Social interaction

It is common to use games as ice-breaking media to bootstrap communication between strangers. This user study had some initial findings in the space of co-located cooperative computer games. We intentionally grouped players so that they had never communicated with the other player before. In the questionnaire, the participants reported that they feel comfortable playing with a stranger (4.2/5); and they have a neutral opinion about whether they think the play experience will be better with a friend (3.2/5). They enjoyed talking with the other player (4.4/5), while they believed that the other player was also willing to communicate (4.1/5). They preferred to play the game with a real person instead of a computer (4/5). The communication includes verbal conversation, hand gestures and body movements. We also observed that all the groups started to talk more after the first round. As participants played longer, their conversation was initiated by and centered around the game play. In some cases, we observed that the two players did not talk at all for as long as several minutes during the first round (G2, G6); but they started talking after the first round finished and reported that face-to-face communication contributes to their game play in the interview. The conversations that happened between rounds were typically reflections on the previous game, the "theories" about which strategy may work better, and the plan for the next round. The conversation during the game was concentrated on passing knowledge about the game to the other player, informing the other player about the game status and asking for specific cooperation.

The user study of AoD showed a good amount of player interaction that leveraged social cues, including non-verbal communication.

Summary

AoD is a prototype we designed to understand the effect of tangible interactions in social interaction and communication. I found that players use combined gestures, object maneuvering, and verbal utterance to communicate in a highly contextualized situation. It is interesting to note that players referred to virtual objects that did not exist in the physical world by pointing at or placing physical tokens at certain physical location. Moreover, the other player could understand the meaning of the location and respond correctly to it.

From the studies on *BragFish* and *ARt of Defense*, I have found a great diversity of physical and social interactions between players. Together they draw a picture of how people play Handheld AR games and what kind of social and physical behaviors emerge from such kind of gameplay. The complexity of social interaction in the gameplay user studies also raises the following questions.

1) Players are able to report subjectively how they feel after each game session; how do we tease apart the social enjoyment of the HAR game compared to the general enjoyment from playing games?

2) Social phenomena are complicated; how can researchers extract data that is relevant to the quality of social play?

3) How do we measure the quality of social play?

4) How do we investigate the connection between the game design elements, especially how HAR interfaces are integrated in the design, and the social play experience?

These questions ask what makes a game social and how we study it. To answer these questions and to transfer the knowledge we learned from one or two specific examples of HAR games to other games, I turn to a non-digital game genre, board games, that are known to be social and share similar spatial and social settings as multiplayer HAR games. At the same time, the questions above motivate me to look into theories that can connect moment-to-moment interaction with overall subjective experience and can tell the difference between high-quality social interaction and low-quality interaction with a systematic approach, and analyze the underlying mechanics that build up enjoyable social experience. I searched through the literature in sociology and social psychology, and in the following chapter, I analyze the game experience of board games using the lens of one sociological theory, Interaction Ritual theory.

CHAPTER 6

UNDERSTANDING SOCIAL PLAY IN BOARD GAMES

The previous two HAR game and their user studies yield a rich amount of empirical data about how people play in a shared hybrid space during HAR games. Based on the studies, I raise questions that attempt to understand HAR player experience in the bigger context: how is a HAR game experience different from or similar to other game genres, how best to leverage these existing human skills during gameplay, and how to design the games that enhance social-physical experiences that players enjoy? To understand what makes a game social, I study the gameplay and design elements of board games to inform the design of tabletop HAR games. Board games have evolved for thousands of years and they combine physical and social interactions, and share similar spatial and social settings with HAR games.

Moreover, I start to explore the sociological theories that fit with the space of co-located gaming. Among the literature, I choose Interaction Ritual Theory from micro-sociology and use it as a lens for analyzing the video recordings of board game play sessions. This chapter's goals are two folded: 1) to understand the design elements that make a board game to be social; 2) to try out Interaction Ritual theory as a lens for gameplay data analysis. This chapter starts exploring the second research question of this thesis, "What are the underlying components of an enjoyable co-located social gameplay experience?" by analyzing board game experiences through the lens of Interaction Ritual theory.

This chapter is organized as follows: I first introduce the motivation of this work, and then report the process and findings from the user study on board games. In the end, I discuss implications for HAR games and reflect on the usefulness of the Interaction Ritual theory in understanding social play.

Motivation

When designing tabletop digital games, designers often draw inspiration from board games because of their similarities (e.g., spatial structure, social setting, and physical interaction). As shown in Figure 1, the commercially available augmented reality game, *The Eye of Judgment*, clearly inherits much of its structure and layout from a lineage of traditional fantasy card games, like Magic: The Gathering (Garfield 1993). Indeed, much of the prior work in the tabletop computing has acknowledged that "*the unbroken success of old-fashioned board games clearly relates to the social situation associated with them*" (Magerkurth et al., 2004), and design elements of board games have been analyzed and extracted (Andersen et al., 2004; Mandryk & Maranan, 2002; Zagal et al., 2006) for the purpose of designing digital games. However, the empirical data that may have been used to contribute to inspiring digital tabletop games is sparse in the academic research, with a few exceptions (Woods, 2010). This empirical perspective is fruitful because it bridges the artifact of the game and the player experience by examining the moment-to-moment interactions that players adopt and adapt.

Figure 17. Similar settings of digital tabletop games (left) and traditional board games (right). (Left). "The Eye of Judgment" gameplay in a living room (Courtesy of Ben Kuchera). (Right). "Magic: The Gathering" gameplay at Pro Tour San Diego (The computer screen was just for score keeping) (Courtesy of Alexander Shearer).

I conduct a video analysis of the social play experience of board games. These findings enrich our understanding of the diversity and emergent nature of social play. Moreover, the goal of the user study is to look into social interactions in magnified detail to understand the foundations for players to interact with each other, such as discussing strategies, negotiating outcomes, expressing themselves and making jokes out of the gameplay. For the purpose of designing HAR games, I analyze how design elements of board games contribute to the social play experience, and provide design suggestions that translate these elements from a paper-based medium to the new medium of augmented reality games.

Research Method

The main research method used in this work is qualitative video analysis (Derry, 2007). Based on 262 minutes of videotaped gameplay that included groups of 4-8 players, I extracted, transcribed and categorized social events during gameplay (Figure 18). To understand how these social events contribute to overall social play enjoyment, I adopt the theory of “Interaction Ritual” (IR theory) from micro-sociology, which examines interactions between members of small groups with the aim of explaining how and why certain events are considered meaningful or important to the group.

I picked four different game titles for participants to play with, all of which are contemporary board games, based on their high rank and positive reviews from the website *boardgamegeek.com* (one of the most popular board game online communities). I also considered game diversity in terms of type (competitive, cooperative, and collaborative), genre (strategy or chance), and physical representations (flat surface or multiple surfaces). The games are:

- *Puerto Rico* (Seyfarth, 2002): a strategy game where players compete to maximize their fortune by building factories, growing crops and selling products.

- *Heroscape* (Baker et al., 2004): a combat warfare strategy game that uses a complex board built of interlocking surfaces and miniatures. The group played collaboratively in teams.
- *Fluxx* (Looney & Looney, 1997): a card game that players win by meeting goals. Rules, goals, and activities constantly change based on the cards players draw and play. It is competitive and chance-based, with relatively fewer strategies.
- *Ingenious* (Knizia, 2004): a strategy board game where players collect points for six colors. It can be played competitively or cooperatively.

Participants and Settings of Gameplay


"

Figure 18. Settings of gameplay (screen capture from one session of playing Heroscape)

The board games were played by groups of 4-8 players on a weekly basis. Every week one game title was played for 1-1.5 hours. Fluxx and Ingenious are shorter games, so I captured 2 sessions of Ingenious (one was individual play, another was team play) and 4 sessions of Fluxx. Heroscape and *Puerto Rico* are longer; we captured 1 session of each. In total, 8 game sessions were captured, the duration of sessions range from 17 minutes to 1 hour and 32 minutes. Four of the sessions had a viewer (not a researcher, but another volunteer player) who was present just to watch the play.

I recruited by word-of-mouth. In total, 9 distinct players participated the games; therefore most participated in multiple game sessions. All participants were computer science graduate and undergraduate students at the same university, with ages ranging from 21 to 33. The participants were provided lunch. The participants knew each other as schoolmates, but they did not have significant personal interaction before the gameplay sessions.

Data analysis

Due to the emergent nature of social play, the challenge of analyzing gameplay video is to find the commonality among a large number of incidences that manifest the same type of social interaction in different ways. To address this problem, I choose an inductive method (Derry 2007), allowing themes to emerge from the data.

In total, 262 minutes of gameplay video were captured. The data analysis consisted of a number of steps. First, I transcribed all the social events during the play. The social events are the actions and interactions that involve 2 or more players. In total, 358 social events were transcribed. I also summarized each of the social events into short phrases, and recorded the social and physical behaviors of every player. These included bursts of laughter, smiling, raised voice, normal speech, body movement, and object maneuvering.

Second, one of my colleague researcher and I grouped the event summaries into categories using an affinity diagram (Beyer & Holtzblatt). We printed and cut out these event summaries, and placed the similar ones to each other. In the end, the categories of events emerged as an outcome of this practice.

Third, in the process of writing and reflecting on the data, I use the lens of Interaction Ritual theory for purpose of identifying the moments of interaction that contribute to increasing the level of engagement.

Using Theories in Data Analysis

I was looking for theoretical frameworks highlight different aspects of the relationship between digital and non-digital tabletop games in useful ways. For example, the theory of Remediation (Bolter & Grusin, 2000) could effectively explain how and why conventional forms from board games make sense for digital tabletop games, or Design Patterns and Pattern Languages (Björk & Holopainen, 2005) may inform an analysis of the relationship between game structure and patterns of play. But these theories do not have an emphasis on empirical data, the analysis is mostly done through critical thinking. In the end, I choose to adopt the lens of Collins's Interaction Ritual (IR) theory because it fits well with the context of co-located face-to-face interaction (Collins, 2004). IR theory analyzes the ingredients and outcomes of successful social interaction despite the gaming platforms. Moreover, it roots in ethnomethodology, symbolic interactionism, and emotional sociology (Collins, 2004). The theory grounds itself in empirical data. It has been applied to understand social interactions and engrossment in game studies (Stromberg).

Synthesizing multiple threads of sociological theories, Collins identifies four key ingredients for successful social interactions in his Interaction Ritual Chain model: bodily co-presence (physically assembling in the same space); barrier to outsiders (a sense of who is taking part and who is excluded); mutual focus of attention (awareness of each other's attention, focusing on a common object); and synchronization (common mood or emotional experience) (Collins 2004). Collins used social games as an example of rituals in which game mechanics, rules, and setup have "*been tinkered with over the years in order to make it 'a better game'–which is to say, to provide moments of collective emotion.*" Informed by IR theory, I analyze board/card games and explore how those game design elements influence players' social behaviors.

In next chapter, I discuss the IR theory in greater detail and explain how it is connected to my whole thesis, while in the chapter I focus on using IR theory for analyzing board game experience.

Findings

In total, five categories of social interactions emerged from the data based on the activity that triggered them: Chores, Reflection on gameplay, Strategy, Out-of-Game, and Game Itself (see Table 1).

Table 6: Summary of social interaction category, related behaviors and the underlying board game design elements

Type	List of interaction behaviors	Board game design element
Chores	• Interactions around object maneuvering • Discussion while waiting for someone to take their turn • Enforcing the rules through social agreement • Collaborative learning	• Manual bookkeeping • Turn-taking • Physical objects • Rulebooks
Reflection on Gameplay	• Taking one's move and laughing about it • Discussion referring back to past moves • Discussion between games to reflect on the whole game	• Turn-taking • Shuffling cards and reorganizing the board
Strategies	• Talking about the strategy • Pointing at physical objects to discuss the specifics of a move • Negotiating and changing strategies according to game state	• Physical game pieces • Shared goal of having fun together • Co-located players • Flexibility of rules
Out-of-game	• Talking about out-of-game subjects • Reacting to distractions • Between-session casual chat	• Turn-taking • Shuffling cards and reorganizing the board
Game itself	• Commenting on the rules and setup of the game • Joking about the game language	• Game jargon • Board games as rule-based systems

I elaborate on the first category of social interaction, chores, in the greatest detail. This focus on chores is related to the goal of generating design lessons for HAR games. The main statement drawn from this study is that, while "chores" can be automated in digital games, they essentially can function as a foundation for emerging social play. The other four categories are introduced briefly, even though they are not the focus, both for completeness and because they also provide some interesting insights in relation to chores. Moreover, I adopt the Interaction Ritual theory to interpret the findings presented below. Theories can offer rhetorical powers that "*help us talk about the world by naming important aspects of the conceptual structure and how it maps to the real world*." (Halverson, 2002)

Chores

Traditional board games require the players to facilitate the game play. All board games demand that some tasks be performed to maintain the correct game state, including (but are not limited to) setting up the board, shuffling, distributing, and reading cards, rule acquisition and enforcement (reading and checking the rulebook), moving objects on the board, etc. When designing a digital game, it is a natural to think about leveraging computing power to remove these chores. However, this study found rich social interactions arising from such chores. On the surface level, these social interactions were enabled because chores slowed the pace of the game and created time that players wanted to fill with other activities. But, deeper analysis of players' behaviors surrounding the chores showed evidence of enhanced physical co-presence with the group and an increased awareness of other's actions. These are illustrated by the four representative social interactions surrounding chores that are described below.

Interactions around object maneuvering

Board games usually include physical objects, such as tiles, tokens, dice, boards, and miniatures. To set up the board, shuffle the cards, roll the dice, and exchange objects, players perform physical actions that oftentimes become observable to others, who may comment on or laugh about such actions. In IR theory, one fundamental ingredient for a successful face-to-face social interaction bodily co-presence (Collins 2004). It creates opportunities for participants to signal themselves and monitor others. As put in Goffman's words, "*when nothing eventful is occurring, persons in each other's presence are still nonetheless tracking one another and acting so as to make themselves trackable.*" (Goffman, 1981) Physical objects make such tracking process easier. In the following example of two teams playing Heroscape, the physical action of rolling dice was not for increasing the chance of winning, but instead, the exaggerated actions amplified the intensity and created a higher level of shared emotions.

> *(The team of player A and B moved their miniature and started an attack towards the other team, C and D. To decide whether the attack is successful, B and C were about to roll dice for attack and defense, respectively.)*
> *B had two attack dice. He shook them in the air for a while and put them down. "Two!" B pointed at the two dice and announced it to C.*
> *"Oh no!" said C when he was rolling his defense dice. Although C had six dice, he only got one defense point.*
> *"Yes!!" B and A said together and jumped up.*
> *"Argh!" roared C.*
> *Everyone else laughed.*
> *B raised both arms to show victory and high-fived with A.*

In the above example, the physical actions externalized the tension among players. And as a result, the intensity of emotions was elevated in the group. The actions of object maneuvering contributed to achieving the "synchronization of emotions" as mentioned in IR theory (Collins 2004).

<u>Enforcing the rules through social agreement</u>

Rule enforcement is a chore that is usually handled automatically by digital games, as such activity takes time and is prone to error when done by the players. But we found that players agree on eligibility of certain moves or scores through social interaction, which provides a reason to engage everyone when it is not their turn. The following example illustrates this.

> *B made a move while the rest of the group was engaged in the discussion about the last move.*

B counted how many points she got for this move, and asked, "Can someone else check the points?"
A stopped talking and checked the scores, and found that B counted one point too many. Now everyone else stopped talking about previous move and start to pay attention to the current one.
"Nice try!" C smiled at B.
Everybody laughed.
"Not my fault, you guys were all talking!" B shrugged.

In the above example, the social interactions fell into two threads, which was common in group communications. By the shared activity of rule enforcement, the group formed mutual focus of attention among all participants again, and the thread that was not directly tied to the current state of the game ended.

Players may also push the envelop of game rules through social negotiation, which increases the tension of social play. In the following examples, players tried to form a union against another player who was about to win. This interaction changed the competitive roles assigned by the game rules to cooperative roles.

(D just needed one more color to win. A, B, C tried to stop him by cooperation)
A talked to B, "you can block off one of those two ends."
D said, "Don't do that. I don't want to be greedy."
A said, "That IS being greedy", looking at D.
B said, "It's kind of tricky to block off it here."
A said, "If you block it here, (pointing at the board), he will still get one or two."
C said, "Why should we play for all?"
A said, "Because you will lose if he ends on his turn."
C said, "We will see."
(B looks a bit annoyed when A tried to direct her move again)
D said, "Let her play her turn!"
After B decided his move and placed it down, A commented that, "Oh great, he (D) wins next turn."
D said, "If I have a blue."
A said, "You do (pointing at the rack), otherwise you would thrown your entire hand last time."
D said, "Maybe, I don't have to…"
B smiled.
C said, "Yeah, I think you want to win so you would."

In above example, players re-appropriate their roles through social negotiation. While A tried to persuade others to work together to stop D from winning, D tried to emphasize the rule of turn-taking (i.e., "let her play her turn!"). This emergent behavior is an example of the social agreement for the flexible rule enforcement – the rules serve the purpose of supporting more enjoyable social experience; and the boundary of the rules are pushed, bended and even discarded for the experience (DeKoven 1978).

Interactions and communications when waiting for someone to take a turn

Board game players seemed to be comfortable with reasonable waiting times. While waiting, they discuss about the last move, chitchat about off-game subjects, and talk about the game itself. A turn-based structure not only provides time for conversation, but also allows players to flexibly switch in and out of the center of group attention, or to put it in terms of performance, the roles of performers and spectators. This rhythm of switch prevents the dominating behaviors to happen. Gibson (2003) researched turn-taking behavior patterns in group conversations, and found that people struggle to become the focus of attention. For example, group conversation may end up as "ping-ponging" between two central members while other members retreat to be spectators. In board games, the predefined turn-based structure proceduralized the problem of attention shift, allowing everyone to take turns to become the center of the group attention. In some cases, one player's turn may take much more time than expected, players often reflect on it and joke about it. For example, the game of Fluxx allows the players to constantly change the rules of play, sometimes leading to prolonged turns. The following example shows how players cope with such situations.

(It was A's turn. He had played two cards already.)
After he played the second one, he put down another card, saying, "Now, I take another turn!"
"Oh god", said G, putting his hand against his forehead.
"What?" D raised her voice.
The group continued to make complaint noises and laughter.
"You played a long time. Dirty!" complained C.
A laughed even more and said, "Isn't that great?"
B (who was the next to play) said, "No, I waited forever!"
Everyone laughed.

Collaborative learning about the rules

Learning complicated rules in a new game takes time away from the gameplay and can be tedious, but conversations and interactions among players (e.g., Q&A, correcting illegal moves, explaining the rules, watching others' moves) support the learning process collaboratively and make it part of the gameplay. Players who pick up the rules faster can both pass their understandings to other players, and reinforce their own learning. We found that rulebooks, which are often multipage booklets, are not typically read page-by-page as an instruction manual. Instead, players read them briefly at the beginning, and refer back to them when an unseen situation happens, or to resolve confusion. The following example shows the learning process for a new rule:

> *H played a card that first time appeared in the game.*
> *A (who played this game before) looked at it and said, "Oh, I hate this (rule)!"*
> *G read the rule on the card out loud, "every number now adds one, so it's now draw four…"*
> *A added on G's unfinished sentence, "draw four, play five, keeper limit five."*
> *Everyone was leaning forward towards the card.*
> *C asked, "So do we get three of these?" pointing at two cards in front of him.*
> *"No" A and G answered simultaneously.*
> *Everyone laughed.*

This example shows that collaborative learning was not just for finding out legal moves. Players added their own interpretations and feelings, reminders about the complexities and scope of rule application, and even occasional shorthand for complex concepts and relationships into discussion. Therefore, the relation between collaborative learning and social interaction is reciprocal. Learning rules provides a common topic that every player has interest in, and social interactions make learning more effective and fun.

Other Categories of Social Interactions

Other than the social interactions required for and generated from chores, we also report four other kinds of social interactions, including reflecting on gameplay, discussing strategies, reacting to out-of-game events/subjects, and joking and commenting on the game's content. In table 1, we provide a set of behaviors related to each of the categories based on our video analysis. These four social interactions have also been discussed in the literature.

Our focus in this paper is to discuss how chores enable these other types of interactions that appear more relevant to play strategy and game enjoyment. For example, we found that players tended to point their fingers at certain spots or move objects on the table when discussing the strategy with their teammates. Interestingly, the physical actions also made their intention and strategy perceivable by the other team, who was usually waiting for their turn at that time. Consequently, the competing teams also got involved, even when it was not their turn. Physical actions on the game board and with objects are kinds of chores that can be automated by the computer, but in board games, they create the common ground for understanding the game state. The following example illustrates this.

> *(C and D were discussing the next move.)*
> *D pointed at a few miniatures on the board and suggested some moves to C.*
> *C stood up and leaned forward to see what D was talking about.*
> *A, who is on the other team, grabbed the rule book and started reading. A pointed to some text in the rule book and said, "You can't make that move..."*

Another example is about the chore of score keeping and how it enables the group of players to reflect on their shared game history. In many board games, tokens and physical score boards serve a score keeping purpose for individual players, but also function as a public display for other players to check and keep abreast of each other's status.

> *D picked another token during her turn and placed it on her scoreboard.*
> *B started laughing immediately after she saw that D stocked up on another tobacco token.*
> *D laughed right after B and said, "I am like, (laughter), an old …(laughter, can't discern), there is reek of smoke…like I figured…(interrupted by C)"*
> *C joked, "You should figure out what you get."*
> *D laughed, "Yeah, that's right."*
> *A followed C's joke, "What? What? No no no… I am getting tobacco."*
> *D stopped laughing for a second and asked, "Can we have two boats with the same stuff in it?"*

"You can't." answered B.
A said, "I guess you could have... (interrupted by D)"
D, "I fill all the boats with tobacoo (laughter)"
The group burst into laughter.

In the above example, players' conversations and laughter overlapped repeatedly. Without finishing the sentence, others already understood the joke based on the shared game history, and immediately followed it by laughter or another joke. Jokes, comments, and laughter build on top of each other, and are an indicator of synchronization, one of the key ingredients of successful social interaction (Collins 2004). Moreover, the player who repeated her pattern of play (D) did not seem to realize the amusement in her action caused at the beginning. Only when another player (B) glanced over the tokens was the group laughter initiated. The score keeping tokens were a trigger for this group interaction.

In some other cases, chores become fun through other kinds of social play. For example, joking and playing with the game content can make the chore of learning new rules more fun. In this case, verbal utterances, exaggerations, body language, and facial expressions are all part of the interactions that make learning easier and more memorable. In the following example, players discussed one game rule on a few occasions, which were mostly fun moments and attracted the group attention.

Player H played a card that has "Love" on it, H said, "I will have 'Love'."
Everyone laughed.
A said, "you should keep 'love' (card), not 'war' (card)." (This is a winning condition called 'All you need is love', which requires the love card, but there shouldn't be a war card on the table at that moment. It was the first time this group encountered this rule). A raised his voice and held his fist up to stress on it.
…(Later in this session, H won by meeting the winning condition of "All you need is love")
(Shortly after a new game session just started)
D had to discard a card according to the rule, she decided to give up the "love" card she owned.
A joked, "you don't like 'love' either?
A and D laughed

In summary, chores in the board game may form the basis for and trigger other kinds of social interactions. On the other hand, the social interactions and play may also make the chores less like a tedious task and more like source of fun.

Discussion

In this section, I focus on one category, “chores,” and the need to translate the effects of chores into the new medium of handheld augmented reality (HAR) games. With HAR interface, physical objects are tracked by computer vision technology and digital content is rendered and registered on top of the real world using handheld devices such as high-end mobile phones. With this new form of game, the limitations of non-digital media might be eliminated technically, but designers still need to make informed choices that would facilitate or impair certain social behaviors. I argue that chores, the work required for play to happen, are integral to social play. I agree that games with too many chores can become tedious, and some chores should be automated to create a fluid experience. But, as we have shown, chores are often a source of the fun and social interactions in board games, especially those that occur in a shared physical play space, and are a potential design element for creating novel kinds of social play in HAR games.

The idea of adding chores to digital games is not as counter-intuitive as it might seem: chores already exist in digital games, even though they take on different forms than those seen in the board games studied here. For example, creating avatars, selecting levels, and configuring controls are all chores associated with digital gaming. These chores, however, tend to be private to individual players, and require them to focus on their personal displays. As a starting point, designers might reconsider the usual methods for these common “digital chores”, and make these traditionally private chores public and visible in the shared space. The observations presented in this paper, combined with the lens of Interaction Ritual (IR) theory, suggest that they might become a source of rich social interactions rather than a source of player isolation. In general, an important message is that choices that "socialize" the work needed to play digital games can have profound effects on the overall game experience, and co-located tabletop HAR games present the opportunity to make this work public in a way many other games do not.

In the remainder of this section, I reflect on specific aspects of how the careful introduction of chores into HAR games may lead to the kinds of rich social interactions typically associated with board games.

Performance

An important contributor to social enjoyment in tabletop games is performance, which is supported by turn-based structure and manipulation of physical objects. When it's time to take a turn, a player may enact an elaborate performance of the action to be taken (e.g., when taking another player's piece, a player might dramatically knock it off the board); this performance can cause comedy, suspense, elevation of group tension, and leads to enhanced emotions and group synchronization. In these board games, physical objects act as props for performers on a stage. The process of dramatically acting out gameplay should lead to social enjoyment, according to IR theory.

With HAR interface, physical objects have been used as triggers to virtual events. For example, in *Eye of Judgment*, the tangible objects of cards are placed on the table, recognized by the computer, and initiate a series of animations and sounds. The fact that these physical objects can be props for performers has not been fully explored in HAR games, which may provide opportunities for performances to take place in both the physical and virtual spaces. A player's performance can thus be enhanced by both these worlds, if the game mechanics and simulation behaviors are designed to facilitate performance. For example, in a game where a player is about to play a spell card, they can offer a physical performance by menacingly waving the physical card, and this performance can be digitally enhanced through virtual flame effects and reactions from virtual actors. If the mixed physical/virtual performance is visible to all players, similar kinds of social experiences to those seen in board games may happen in HAR games as well.

Virtual Voyeurism

Social play happens when people fully share a play experience. As we pointed out above, digital games already have chores, typically purely virtual chores that are performed by individual players (e.g., choosing the type of spell to perform in a turn, changing an avatar's costume or weapons, etc.). When appropriate for the game, these chores can be moved from the purely virtual space of a player's device into the shared playspace. For example, if a player needs to assemble a virtual team to overcome an obstacle in the game, the team can be assembled and configured on the edge of the gameboard, for all to see. Perhaps not all aspects of the team are visible, but by exposing the virtual manifestations of the players virtual chores in the shared playspace, all players are aware of what each other are doing. These can be transformed into social performances by giving players control over when and how different aspects of their activities become publicly visible to other players.

Turn-based vs. Continuous Play

Although turn-based structure in board games is largely a result of the non-digital medium, we find group interactions benefit from it by the imposed rhythm of turn-taking. Players switch in-and-out of the center of group attention, and give attention to and receive attention from other players regularly. The side effect of a turn-based structure is to create time and space for players to synchronize with each other's game play and emotional experience, which is universally important for digital and non-digital games. HAR games have the flexibility of choosing continuous or turn-based game structures or to combine them. To translate the essence of turn-taking to HAR games, other designs can be integrated in continuous games that have a similar effect of turn-taking. For example, in some digital games designed for group play, only one controller is used so that there is only one person playing at any moment, the rest become the audience. The key is to find structures such that everyone is paying attention to, and receiving attention from, other players. This attention provides a basis for communication and interaction.

Appropriation and Flexible Play

Digital games have a tendency to have rigid pre-programmed rules that are automatically enforced by the game. On one hand, this approach is beneficial because it simplifies game programming and makes the games understandable and approachable. Having the computer enforce the rules reduces housekeeping and rule-enforcement chores on the part of the players. However, it may also create a rigidity that limits social interactions that might evolve when a game environment is appropriated by the players to create variations not foreseen or intended by the game's creators, as often happens in traditional tabletop games. Groups often change or negotiate the rules of tabletop games (creating "house rules"), either to give advantages to novice players, or because they want to have a different game experience. There are examples of so-called "sandbox" games, but they are not common (usually because they are so difficult to create with digital media). We believe that the flexibility afforded by such open games is particular appropriate for creating social experiences in HAR games.

Summary

In the empirical data analysis, I explore how the key ingredients of successful social interaction, including bodily presence, mutual focus of attention and synchronization of emotions, are supported in board games. Players maneuver physical objects and talk to each other, which makes these actions more observable and trackable to other players, enhancing co-presence and increasing the awareness of other players. During the game, players share the common interests about the game, its rules and their gameplay. Every player can comment on or laugh about these topics, the accumulated interaction history that reinforces synchronization of emotions among players. With the turn-based structure, players take turns becoming the group's attention center; when it is not a player's turn, there are different ways that they can engage with the group activities, such as learning new rules, checking results during others' turns, reflecting on someone's move or partially participating in the decision making for another move. In summary, board games engage players with each other (rather than just immerse players in their individual gaming spheres) through the tasks that make game actions and game status observable to others.

As shown in the process of data analysis and report, the use of Interaction Ritual theory provides a cohesive system that helps researchers identify and name the key design elements that support social play. The role of theory is especially important for the complicated social interaction phenomenon, which carries an overwhelmingly large amount of information. In this chapter, I show that Interaction Ritual theory is an effective tool for analyzing board game social play experience, providing insights in the important parts of empirical data that would otherwise be harder to notice.

CHAPTER 7

THEORY-BASED ANALYSIS ON SOCIAL PLAY

The studies of the gameplay during *BragFish* and *ARt of Defense* yield a diversity of social interactions that range from an intuitive way to refer to physical-digital objects, to physical movements taken as indicators for strategies and player intentions. These findings address the research question of "what kind of social play behaviors emerges from multiplayer HAR games?" The results provide empirical evidence that HAR interface can be designed to enable and support the interactions among players.

However, it remains unclear what underlying elements and procedures compose an enjoyable social gameplay experience in a shared hybrid space (RQ2). Therefore, in the last chapter, I analyze board game experiences through the lens of a sociological theory, to start exploring the following questions: what makes a game 'social'? How do researchers connect the moment-to-moment to the overall game experience that players remember and talk about? Why do certain design choices that tend to encourage social play behaviors emerge? What is the role of game interfaces in supporting these behaviors?

In the data analysis on board games experience, sociological theories have shown descriptive and rhetoric power in identifying and naming the key elements of social play. In this chapter, I take this theory-based approach further, and synthesize different threads of theories to accommodate the need of understanding and designing for social play in shared hybrid spaces.

In the Research-through-Design method, theoretical exploration feeds into the interaction design, providing knowledge of what is "true" about human behaviors. I adopt and adapt theories from sociology by using them to analyze the existing empirical studies on co-located games, which are cited from HCI, CSCW, and game research domains.

Moreover, based on the analysis, I generate theory-based design guidelines for co-located games in a shared hybrid space.

In this chapter, I first discuss why sociological theories are needed to understand social play. Then I introduce the two sociological theories that I choose from the literature of sociology, including Interaction Ritual Theory by Collins (Collins, 2004) and Frame Analysis by Goffman (Goffman, 1974). To adapt them to social games, I use them as a lens to reanalyze prior empirical studies on co-located multiplayer games, including Handheld Augmented Reality (HAR) games. In the end, I summarize a set of theory-based design guideline for co-located social games.

The Need for Sociological Theories in Game Research

The most well-known psychological theory adopted for game research and design is the "flow" theory from positive psychology, referring to the mental state of high level concentration and loss of self-consciousness or sense of time (Csikszentmihalyi, 1990; Voida et al., 2010). Flow theory has been widely cited by game scholars for the purposes of interpreting empirical findings, describing gameplay phenomena (Cowley et al., 2008), providing design guidelines (Chen, 2007), and generating evaluation metrics (Sweetser & Wyeth, 2005). However, researchers have also spotted a gap between flow theory and social play, as noted by Sweeter and Wyeth, "*social interaction is not an element of flow, and can often interrupt immersion in games… However, it is clearly a strong element of enjoyment in games*" (Sweetser & Wyeth, 2005).

To bridge this gap, some game researchers and designers have set out to create intermediate concepts between flow and social play. DeKoven created a new interpretation of flow in the realm of social games, named "CoLiberation", a balance between individual identity and group connectedness (DeKoven, 1978). In parallel to the skill-challenge balance in a flow experience that avoids the emotions of anxiety and boredom, "CoLiberation" is a balance between oneself and the group, escaping from alienation (too much “me”) and conformity (too much “we”) (DeKoven, 1978). By reaching this balance, a player gets engaged in gameplay on both individual and group level. Furthermore, Pearce raised the concept of “intersubjective flow”, building on both flow and CoLiberation, to explain the emergent phenomenon in online game communities that players generate social bonds over a short time frame and reach an “in-sync” state (Pearce, 2009).

The work above highlights points out the co-existence of players’ engagement on individual and group levels. Nevertheless, it is not immediately obvious how to translate from these conceptual constructs to the moment-to-moment interactions of social play, and to the overall player experience. This problem is also witnessed by de Kort and Ijsselsteijn, “*Given the growing anecdotal and empirical support for the social richness of digital gaming, it is increasingly surprising that social process and interpersonal dynamics are underrepresented in conceptualizations and theories of game experience and enjoyment*.” (De Kort & Ijsselsteijn, 2008) Without conceptualizations and theories that researchers agree upon, user studies of games each adopt different evaluation metrics, making it difficult to compare and analyze player experience across different game titles or genres.

In my work, the goal is to fill this missing link by choosing, adopting, and adapting theories that decipher social play more than a collection of observable player behaviors, but as a process that these behaviors interweave with and reinforce each other.

To understand inter-personal social play and enjoyment, I turned to sociological theories that 1) focus on inter-subjectivity, the situation between individuals, and 2) explain the cause, process, and outcome of enjoyable social play experience.

Introducing Theories to Understand Co-located Social Play

Game researchers have gained much insight from adopting psychological and sociological theories to design for the sociability and social interactions in games (De

Kort & Ijsselsteijn, 2008; Isbister, 2006; Isbister, 2010). They recognize and draw upon the rich body of knowledge from social scientists such as Social Psychologists, Anthropologists, Communication scholars, and Sociologists. The most cited theories in include interpersonal spatial configuration (Hall, 1966), bodily presence (Strack et al., 1988), emotional contagion (Hatfield et al., 1994; Iacoboni et al., 1999), and goal relevance (Blascovich et al., 1999). These theories shed light on understanding the salient and hidden factors that may affect the social play experience qualitatively and quantitatively. But a big challenge is to integrate these theories cohesively to understand their interconnected roles in the social dynamics and process during social games. A second challenge is that these theories were not generated from studying gameplay behaviors, many of which did not consider the roles of artifacts, rules, and media in the social interaction. Among the literature, I choose two social theories that are overarching and highly relevant to co-located game research.

I have adopted and adapted Collins's Interaction Ritual (IR) Theory (Collins, 2004) and Goffman's Frame Analysis (Goffman, 1974) to my work.

IR theory is created to understand "*the small scale, the here-and-now of face-to-face interaction.*" (p1, (Collins, 2004)), which is a good fit with my focus on co-located social play experience. As shown in the chapter 6, IR theory provides a useful vocabulary to analyze and talk about co-located social play. Moreover, IR theory is a synthesizing theory. Many of the theories mentioned in the last paragraph can be considered as ingredients in the IR Model, and the relations between these ingredients are illustrated in IR theory. But IR theory does not take in account the co-existence of the game world and the real world or the overlapping physical and digital spaces.

To fill this gap, I integrate Goffman's Frame Analysis to emphasize the boundaries and integration between physical and digital worlds, and physical and digital spaces. The following two sections introduce IR theory and Frame Analysis in greater details, and discuss why they were chosen for the exploration of social play.

Interaction Ritual Theory (IR Theory)

IR Theory was created to understand the elementary processes that underpin all social interactions; this theory analyzes the ingredients and outcomes of successful social interactions of small groups in mundane everyday life. This theory is built on top of the sociologists Durkheim's work on rituals (Durkheim et al., 1965) and Goffman's work on interaction analysis (Goffman, 1967), as well as the rich literature in symbolic interaction, ethnomethodology, sociology of emotions, and social constructionism. Specially, in the book "Interaction Ritual Chains", Collins points out four key ingredients for successful social interactions in his Interaction Ritual model—bodily co-presence (physically assembling in the same space), barrier to outsiders (a sense of who is taking part and who is excluded), mutual focus of attention (awareness of each other's attention focusing on a common object), and synchronization of emotions (common mood or emotional experience that gets elevated during the interactions) (Figure 19, P48, (Collins, 2004)).

IR theory synthesizes multiple theories and research from social science. For each of these factors, there are underlying theories that support them, such as theories about joint attention (Mead, 1967), body positioning and orientation (Kendon, 1970), and conversation synchronization (Chapple, 1981). These factors are interlinked: bodily presence and boundary to outsiders allow people to keep track of a certain range of people's actions and reactions, which forms a foundation for them to gain awareness of each other's actions and attention. When they have mutual focus of attention, participants express and share their emotional reactions. As their emotions are observed, they stimulate more responses, forming a feedback loop that tends to intensify the shared experience among people.

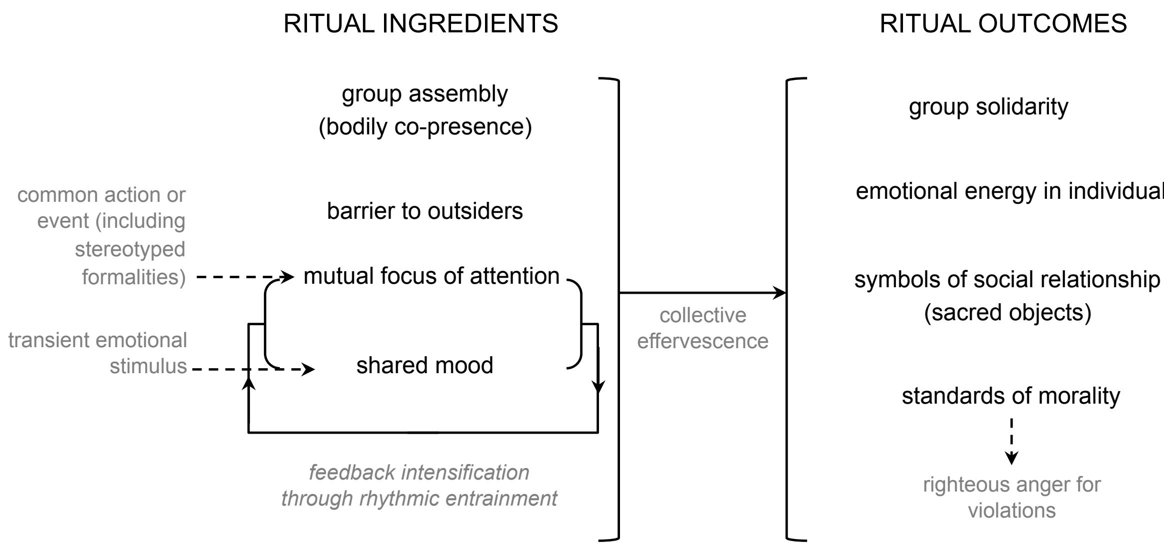


Figure 19. Model of interaction ritual theory, Collins 2004, P48 (Collins, 2004)

Successful rituals produce a sense of group solidarity, which is represented in symbolic emblems. Individuals will want to repeat this interaction again with enthusiasm and confidence (which is referred to as emotional energy in the IR theory). The group tends to develop moral standards of what is right or wrong, punishing those who violate its symbolic code (Collins, 2004).

Interaction Ritual theory has started to be adopted in multiple areas that require understanding group dynamics, such as the role of mobile technology in communication (Ling, 2008), religious practices (Heider & Warner, 2010) and game engagement (Stromberg, 2009). The experiential goals in IR theory and game experience naturally fit. As Collins wrote,

> "Games are rituals, contrived to produce situations of dramatic tension and victory; the rules of scoring and moving into position to score have been tinkered with over the years in order to make it 'a better game'–which is to say, to provide moments of collective emotion…Games are natural rituals in so far as they unconsciously or nondeliborately bring about the ingredients for a successful ritual…and they bring together a community that has no other coherence, and no other purpose, than the experience of the peaks of ritual emotion itself." ((Collins, 2004), P58-59)

For my research on co-located digital-physical social games, a sub category of social games, IR theory is a good fit because:

- The user scenarios of co-located games match with those scenarios from which Interaction Ritual theory was generated;
- IR theory focuses on emotions as an ingredient and outcome of social interactions, instead of productivity of tasks;
- IR theory breaks down the complicated social phenomena into composing elements and explains why some social interactions are enjoyable or not.

However, IR theory was generated for everyday life interactions rather than game scenarios. It does not account for the co-existence of a game world and the real life world, or the boundaries and blending between physical and digital spaces. The meaning of people's actions and communication are mapped and interpreted in a game system, which may be different from real world norms and rules. To solve this problem, I integrate frame analysis into IR theory.

Frame Analysis

Goffman defines a frame as "*a situational definition constructed in accord with organizing principles that govern both the events themselves and participant's' experience of these events.*" ((Goffman, 1974), p10-11) Games are engrossment systems that provide their own meaning systems, and players' perceptions, actions and communications can be interpreted according to this system. Sociologists have recognized the existence of finite worlds of meaning that "*have the potential for allowing human beings to become encapsulated in* them" (Fine, 1983).

Games create frames grounded in reality. As put by Fine,

> "Games are quite essential examples for frame analysis because of their capacity for inducing engrossment. That is, voluntarily cutting oneself off from other realms of experience distinguishes this world of meaning from those primary frameworks (for the paramount reality) that individuals

> 'naturally' inhabit…The significance of gaming resides in *the shared nature of the engrossment*, and in *the supportive recognition that others are equally engrossed*." (P182, (Fine, 1983))

Fine introduced the frame analysis into tabletop role-playing games (e.g., Dungeons and Dragons). He insightfully highlighted that participants of tabletop role-playing games experience three frames: as a person (using commonsense real world knowledge), as a player (who understands the rules of the game), and as a game character (whom a player has access to as the game progresses) (Fine, 1983). His analysis focuses on how people easily switch between frames.

> "Frames succeed each other with remarkable rapidity; in conversations, people slip and slide among frames. Engrossment, then need not imply a permanent orientation toward experience."

As shown in his empirical findings, the boundaries between these frames blurred and played with, and players seem to be good at switching between frames. Along the same line, researchers have adopted Frame Analysis to reexamine the "magic circle" concept (brought forward in (Huizinga, 1955) introduced to game research by Salen and Zimmerman (Salen & Zimmerman)). Gameplay is not separated from, but integrated in the mundane everyday life (Consalvo, 2009; Pargman & Jakobsson, 2008; Schrank, 2011). Goffman discussed the dual relations between these game frames and the frame of real life: "*a wider world must be introduced, but in a controlled and disguised manner*." A game may transfer values externally recognized in real world into the gameplay (e.g., courage, dexterity, intelligence), but they also need to keep a "*symbolic distance*" from reality, otherwise it starts to "*come too close to home.*" (Goffman, 1961) Players project themselves into the game in a "*safely transformed manner*." (Goffman, 1961) This dual relation between reality and game can be reflected in social games that walk on the boundary between frames. For example, spin the bottle, as analyzed in (Salen & Zimmerman, 2004), disguises the social behaviors that are potentially inappropriate or run the risk of rejection in real life into a game that creates a socially safe place for players. The fact that these social behaviors are “forbidden” in real life makes it more exciting for participants to try them in the game.

Other than the real world and game world frame switch, game designers and researchers also consider mapping between digital and physical frames. For games that leverage reality-based interfaces, the phenomenological division between the digital and physical spaces is blurred. The physical actions and social communications that account for certain meanings in physical world can be naturally mapped into the digital world and assigned with new (and related) meaning there. Designing games with reality-based interfaces requires blending and differentiating the two frames of digital and physical worlds.

For the players it is natural to switch between different frames. In fact, some of the switching happens subconsciously. But for game designers, they need to be aware of how to design for the switch between frames (game vs. reality; digital vs. physical) and design the game so that for players this becomes invisible. Game equipment and interface (i.e., the play material) is one of the connecting points between frames. As pointed out by Goffman in his essay of “Fun in Games,” he discussed how “game equipment” evokes players’ subjective reactions through its aesthetics, sensory, and material, which can be transferred from real world context to their roles in the game. Examples in game history show that the change of game equipment also reflect their meanings in real world (e.g. the introduction of chess queens reflect political changes in European history (Yalom, 2005)). Taking the perspective of frame analysis, the choice of game interfaces and its consequential design decisions can be viewed as choices about how to support players to connect and distinguish between frames.

In summary, I adopt Frame Analysis because of the co-existence of frames in modern game design. In a social game scenario, frames are co-created and reinforced among the players. We design game systems to support players to switch in-between frames in an intuitive way.

Adapting Theories for Social Play

I combine and adapt both Interaction Ritual Theory and Frame Analysis to the domain of social games. Combining these two theories raises new questions, such as: The bodily presence normally happens among people in an encounter, but also does it exist between players' in-game representations? Human beings seem to be naturally in tune with each other's movements, facial expressions, and mood in the same physical space, but under what circumstances such skills get translated into gameplay? With rich digital media pulling people's attention into the graphical world, how do people distribute their attention between the game and other players?

To answer above questions and test the usefulness of these theories, I analyze each ingredient mentioned in IR theory based on a number of existing empirical findings of co-located digital and non-digital game experiences, including handheld console games (Szentgyorgyi et al., 2008), living room console games ((Lindley, 2008; Seif El-Nasr, 2010; Voida et al., 2010; Voida & Greenberg, 2009), pick-up basketball games(Jimerson, 1999), board and card games (Salen & Zimmerman, 2004; Woods, 2010; Xu et al., 2011a), arcade dancing game (Lin & Sun, 2011), and tabletop digital-physical games (Henrysson et al., 2005; Leitner et al., 2009; Xu et al., 2008). These games are highly relevant to co-located HAR games, representing both the physical and digital aspects of such games. The outcome of this analysis is a list of design guidelines for co-located social games.

Bodily Presence

In IR theory, bodily presence is the beginning of the interaction ritual process. People are naturally able to keep track of each other, even when it is not their focus of attention, as noted by Goffman:

> "When nothing eventful is occurring, persons in each other's presence are still nonetheless tracking on another and acting so as to make themselves trackable." ((Goffman, 1981), p103)

The ability of people to keep track of each other's actions forms a foundation for other ingredients in the IR model. Moreover, bodily presence supports emotional contagion, which also reinforces participants' own emotions. As put by Collins,

> "Above all, one seeks the sound of the crowd, to share fully the sense of excitement. This is essentially what the lure of the game-spectacle is all about: the pleasure of those moments of having one's own emotions raised by noisy crowd expressing the same thing." ((Collins, 2004), p55)

In co-located games where players share the physical-digital space, designers are given the opportunity to leverage players' bodily co-presence. Some games, however, failed to take advantage of that. In Szentgyorgyi et al's study on Nintendo DS games, they found that players did not have much social interaction during play. It is worth noting that they also found that players tended to sit next to each other even the network connect works with a range of 30-100 feet, and they also arranged their body orientation to form a semi-circle that allowed them to have face-to-face interaction (Szentgyorgyi et al., 2008). This contrast shows that although players had the intention of having more social interactions (as expressed by their body distance and orientation), sitting close to each does not automatically make a game social (De Kort & Ijsselsteijn, 2008; Jakobs et al., 1997). Because the games did not motivate players to observe the other player's real world physical movements, facial expressions or utterance, players were not motivated to pay attention to the other players in action. Using Frame Analysis to explain this phenomenon, the meaning of bodily presence is lost when a digital game does not intentionally incorporate it. Players' attention was instead dominated by the individual gaming activities, which decided their performance in the game.

In contrast, in board games and card games such as Mafia and Little Max (as analyzed in (Salen & Zimmerman, 2004), page 467-472), to win the game, a player is motivated to leverage bodily presence. *First*, players need to use their existing social skills to keep track of what others have said or done during the game, and also try to mislead opponents by bluffing and hiding information. *Secondly*, the interpersonal spatial arrangement in board games makes it easy to observe others and be observed. With the setting that players sit around a table facing each other, players form an F-formation circle in which each participant has equal and maximized ability to observe others (Kendon, 1975). *Thirdly*, board games do not automatically deal cards, roll dices, or move the pieces, these actions have to be carried out using physical movement and object manipulation, which in turn make these actions more explicit and easier to keep track of. The emotional contagion effect of bodily co-presence is also well integrated in board games. When players get engrossed, they jump out of the seats, raise their voices, burst into laughter, give high-fives, and hug each other. Physical ways of expressing oneself and bodily contact with others increase player engagement with each other.

Reality-based interface can enhance the social play experience by displaying more information through physical actions, which may lead to further communication and interaction. Lindley et al.'s comparative experiment of people playing Donkey Konga with the Bongo interface or GameCube controllers found that players have higher frequency of verbal, non-verbal, and gestural interaction using the physical interface of Bongo (Lindley, 2008). They explain that with a reality-based interface, "*players display information about their interactions with a game through their movement, making their use of the device as a rich source of consequential communications*." (Lindley, 2008) The consequential effect of body movement is also found in my study on BragFish (Xu et al., 2008). We found that some players adopted the strategy of inferring the other player's intention by observing their body movement. With the natural mapping between players' physical movement and their avatar's, players can easily leverage their bodily presence to perform game events and also observe others' progress through both physical movement and digital representations.

In summary, the above analysis of three genres of social games (i.e., handheld games, board games, and games with reality-based interfaces) shows that players are able to actively take advantage of their bodily presence when it has corresponding meaning in the frame of the game. Although being physically close gives players multi-modal channels of interactions and real-time action-reaction loop, it does not guarantee that a game will be social. To fully leverage players' physical presence in social games, game designers can 1) map the players' physical presence intuitively to their in-game presence, so that it is easier for players to display their game state and perceive others' game state through bodily actions; and 2) motivate players to pay close attention to other's physical presence (e.g., movement, gestures, facial expressions) by integrating it in the game.

Barrier to the Outsiders

The participants, by committing to be part of the activity, form a circle that has entry barriers for outsiders. Huizinga's "magic circle" concept resonates with this ingredient. He wrote:

> "It (play) promotes the formation of social groupings which tend to surround themselves with secrecy and to stress their difference from the common world by disguise or other means." (Huizinga, 1955)

In this section, I focus my analysis on the reverse side of the barrier—how a co-located multiplayer game gets players and spectators involved. Specifically I investigate two questions: 1) how is a game initiated, especially among strangers who are not connected via an existing social relationship? and, 2) how can a game support spectator experience?

<u>Game Initiation</u>

For multiplayer handheld console games, one of the biggest problems reported in the literature is the lack of social etiquette to initiate or exit an ad-hoc game (Szentgyorgyi et al., 2008). As discussed in (Szentgyorgyi et al., 2008), the difficult of initiating an ad-hoc multiplayer Nintendo DS game was not caused by technical challenges. In fact, Nintendo DS provide a decent technical solution to address the issue that not everyone owns the multiplayer game title that they may want to join. Through the function called “Download Play”, a player downloads a temporary copy of a game to join the group for at least one session. However, it is socially awkward to approach a stranger and ask them to play a networked DS game (Szentgyorgyi et al., 2008).

In contrast, for pick-up basketball games, being at the same location of basketball field is a clear indicator of interest. Researchers also found that players use “ritualized scripts” to join and exit a game (Jimerson, 1999). To support players initiating an ad-hoc digital game with strangers, we need to have some signaling mechanism and social etiquette. People start to experiment different ways to do so, such as wearing DS buttons (a physical button produced by a third party that display distinct logos tied to backpacks, clothes, jackets) (Szentgyorgyi et al., 2008) and carrying Nintendo DS visibly. In the more recent Nintendo 3DS games (e.g., Wii Street Pass), a game device has the capability to automatically connect with other devices. A player can turn this capability on or off. These emerging ways of connecting handheld game players shows an interesting shift. Instead of relying on socially accepted conventions (e.g., breaking the ice by a ritualized script), DS players use the game equipment’s physical presence (including symbols of the game device) and its digital presence to initiate the ad-hoc games.

Spectator Experience

There are several circles of participation in social games (Reeves & Benford, 2005). For example, in a football game, there are sports players, the audience at the stadium, and the TV audience. Between these circles, players and peripheral participants reinforce each other’s emotions (Collins, 2004).

However, handheld devices are critiqued to be unable to support spectator experience because of its “secretive” nature, which makes user actions and system feedbacks invisible to spectators (Reeves & Benford, 2005) For example, in the following writing, the authors attribute the lack of spectator experience in Nintendo DS games to its hard-to-notice input actions and the small display (Szentgyorgyi et al., 2008).

> The player’s manipulations, usually pushing buttons or drawing with the stylus, are largely hidden due to the DS’s small size, as are the results of those manipulations on the game state. P3 commented that while others not currently playing would watch and make comments on console play, it was harder to “stare over someone’s shoulder” to watch the DS, so people were not interested in watching.

Granted, big displays support spectators watching the game in the distance. However, I find it an oversimplification that the device size is taken as the main reason for the lack of spectator enjoyment. In many card games, the “interface” of private cards is even more secretive, and players even try to hide or mislead others from guessing what cards they have, but this does not stop card games from being highly inclusive of spectators. In an informal setting, spectators can keep track of the game state and comment on the game. The reason why they can do so is because game events and progress is revealed through the actions and communications among the players, meaning that other than relying solely on the digital display to show the game state, game players themselves are “displays” highly observable and responsive to spectators. Designers can also try to make interactions in the physical-digital space eventful, observable, and relevant to the game.

The spectator experience is not simply the outer layers of gameplay, but also contributes back to the players’ experience. Lin et al.’s observation and analysis on arcade dancing game show that with the presence of spectators, a player can experience the game in different frames, including “show room”, “gymnasium”, and “clubroom.” (Lin & Sun, 2011) These frames differ in the quality of social interactions between players and spectators.

In summary, I adapt the “boundary to outsiders” ingredient from IR theory to co-located social games by focusing on how to facilitate participation as a player and a spectator. How to display the information about the game, not only limited to digital display, is an important question to answer even before a game starts. Handheld devices face challenges of mobility and small display in initiating a multiplayer game and supporting audience's awareness of the game. It needs to learn from other social games to display game-related information with other channels, such as verbal and non-verbal communications and bodily languages.

Mutual focus of Attention

Mutual focus of attention is not only paying attention to the same object or activity, but also being aware of others' attention to the same target (Mead, 1967). By doing so, people can understand each other's actions and emotions. Moreover, this allows people to try to ascribe a sense of intention to the others, which precedes their actions (Tomasello, 1999).

Mutual focus of attention is a core construct in IR. In a co-located social interaction scenario, it is the foundation for inter-subjectivity to emerge from shared activities and objects. As Goffman explains:

> "Something in which the individuals can become unselfconsciously engrossed is something that the individuals can become real to him. Events that occur in his immediate physical presence are ones in which he can become easily engrossed. Joint engrossment in something with others reinforces the reality carved out by the individual's attention, even while subjecting this entrancement to the destructive distractions that the others are now in a position to cause."

The above quote highlights three key points. First, what is "real" is "carved out by the individual's attention", instead of the objective "realness". Second, people can reinforce a shared reality through "joint engrossment", which is group participants' belief that the "carved-out reality" of others is aligned with theirs. Third, the "joint engrossment" is under the risk of destruction from others as well.

With understanding on mutual focus of attention and its role in social interaction, I explore its implications for social game design. To break down the micro-procedure of supporting mutual focus of attention, I ask three questions:

1) How is a player's attention distributed in a game?

2) How can we join multiple players' attention together?

3) How is it possible to motivate players to be aware of other players' attention?

I use examples from game design and game research to answer the questions above. It is challenging to direct players' attention to a common object of interest in digital games, in which players' attention tends to split between multiple targets: display (e.g. game characters, game world, UI, etc.), acoustic and haptic feedback, other's players' actions and reactions, and so on. Game designers have used visual, haptic, and acoustic cues to subtly direct players' attention in the game space (Nitsche, 2009; Walz, 2010). More importantly, to make a play experience "social", the game needs to direct the attention of multiple players to the same object to support a mutual focus of attention to happen.

There are several approaches to achieve this goal, leading to qualitatively different social experience. In some genres, "parallel play" (defined as "solitary activities in the presence of peers" by Parten (Parten, 1932)) is enabled through the same game object that is independent of individual actions. For example, rhythm games (e.g., Rock Band (on Xbox), Just Dance (on Wii), Dance Central (on Xbox Kinect)) directs players' attention to the common object of melody which synchronizes the actions of multiple players. Although the group performance depends on the sum of individual performances in the cooperative game mode, the players can keep the minimum amount of interaction during the game.

Comparatively, some other game genres tend to direct players' attention to shared objects and activities that can be directly influenced by individual players' actions. Seif El-Nasr et al.'s empirical study on cooperative games summarized a dozen of design patterns that may lead to cooperative game behaviors (Seif El-Nasr, 2010). Among these patterns, "interacting with the same object", "shared goals", "shared characters", and "shared puzzles" fall into this category. Although their discussion is under the context of co-located cooperative game, these patterns are useful to other types of social games (i.e., competitive and team-based competitive games) because they support players to join attention and have consequential interaction. When players focus on the same object/goal/character/puzzle, they negotiate with each other to interact with the common target. In some cases, it introduced direct competition to earn the control of the objects. For example, team sports often include a game object that players fight for, such as a basketball or football. In other cases, players work out strategies and division of labor to perform more efficiently as a team. In summary, shared objects and activities that can be affected by multiple players can be leveraged to support a diversity of social interactions.

A third approach to join players' attention is to direct their attention to other players or their avatars. In digital games, the attention is often directed to a player's avatar, while in non-digital games, it is directed to the other player. For example, in my video analysis of board games, I discuss the role of turn-taking structure in fostering social interaction. During a board game, players take turns to perform their actions while other players are watching. This means that players take turns being a performer (during own turn) and a spectator (on others' turns). The group joins their attention on the performing player during their turn. The importance of the turn-taking structure in creating a shared reality among players was analyzed by Goffman:

> "The developing line built up by the alternating, interlocking moves of the players can thus maintain sole claim upon the attention of the participants, thereby facilitating the game's power to constitute the current reality of its players and to engross them." (Goffman, 1961)

The non-digital medium of board games also contributes to supporting players in maintaining "sole claim upon the attention of the participants". In board games, the game events can only be carried out through other players' actions. However, in digital games, many aspects compete for players' attention, such as animated objects, rich multi-modal feedback and game AI. In digital games, directing players' attention onto other players requires explicit motivation to be integrated in the gameplay. To achieve this goal, design patterns of cooperative games, such as “complementarity” (complementing each other’s activities), “synergies between abilities” (assisting or enhancing capabilities of other players), “abilities that can only be used on another player” (J. B. Rocha, 2008), have been created to increase the dependency between players (and their avatars), thus motivating players to pay attention to each other in cooperative games.

Failing to support mutual focus of attention may lead to missed opportunities for social interaction and synchronization among players. In the study of multiplayer Nintendo DS games, the authors found that each player is immersed in their own “private game sphere”, meaning that players have separate experiences with the small mobile device that they are constantly engaged in (Szentgyorgyi et al., 2008). Although in the paper the authors attribute this mostly to the small display, I believe that the lack of mutual focus of attention may provide a deeper explanation as to why a multiplayer game leads to solitary experiences. *First*, players’ interaction with the game world occupies most of their attention. *Second*, the in-game camera setting and small screen makes it harder to observe others’ game state through the screen. *Third*, players are not motivated to pay attention to a common object or other players to win. Considering the above factors, players share little mutual focus of attention during the game, and the players self-rated the multiplayer DS game experience to be less social than a living room console game.

In summary, the above studies of various genres of co-located games show that it is important to provide meaning and motivation for players to pay close attention to each other and to common objects. In the case of the games with reality-based interfaces, the common objects could be digital or physical. I summarize three ways that a designer can use to support mutual focus of attention among players: through shared game objects that are independent of players, through common objects and activities that can be affected by individual players, and by motivating players to direct their attention to other players. Each of these methods fosters qualitatively different social experience.

Shared Mood

When people's interaction becomes more engrossing, they get more caught up in the similar rhythm and mood. This ingredient resonates with the emotional contagion (Hatfield et al., 1994; Iacoboni, 2009) discussed in the literature. According to the IR theory, shared mood and mutual focus of attention reinforce each other. Emotion is a central ingredient and outcome of IRs. Collins emphasized that "*what makes or breaks a ritual the extent to which the group builds up a strong collective emotion*." The shared mood can be empirically shown as shared laughter, conversational rhythms and synchronized movements.

Shared mood is what a good social interaction and what a good social game has in common. Both indicate the synchronization between participations. The difference is that, in most of the natural rituals of social interaction, such as a conversation, the shared mood is an emergent pattern between participants while in social games the emotioneering (Freeman, 2004) of the game design plays a critical role in supporting and fostering the shared mood between players. In the design of social games, we ask, what are the mechanics that may lead to a shared mood?

One of the most common emotions during a gameplay is laughter. Shared laughter was included in the metrics for cooperative game behaviors. To use the IR theory to explain why it is satisfying, Collins wrote,

> "The sounds of the laughter is bodily produced by a rhythmic repetition of breaths caught and forcefully expelled; at the height of hilarity, this happens involuntarily. Most laughter (and its strongest intensity and pleasure) is collectively pronounced. Once laughter begins, it can feed upon itself."

Seif et al. found that shared laughter in a cooperative game is most likely to happen with the animations, cut scenes, or special elements that are specific to one game. Other causes for shared laughter include shared goals, complementarity, shared puzzles, and shared characters. Similar findings were also found for board games. In my previous analysis, I found that shared laughter is evoked by game-content related jokes, funny comments on previous moves, shared game history, and exaggerated physical actions. Sometimes the jokes do not even look to be funny from the researchers' eyes as an outsider, but they become amusing because the players had the shared experience and their mood was built up to a level, getting tuned enough that the fun is magnified. In some occasions, players' conversations and laughter overlapped repeatedly. Without finishing the sentence, others already understood the joke based on the shared game history, and immediately followed it by laughter or another joke. Jokes, comments, and laughter build on top of each other, and are an indicator of high level of synchronization.

In IR theory, mutual focus of attention and shared mood reinforce each other. In the above findings from studies on board games and console games, the game designs found to be effective in supporting shared mood all provide a common target that players are aware of, whether it is game-based (such as cut scenes, funny animations, creative narratives) and shared goals/characters; or player-generated (such as shared history built through multiple game experiences and other out-of-game shared history).

The shared mood is a meta-goal of gameplay. DeKoven wrote about player's behavior of handicapping themselves to accommodate the enjoyment with the group that has uneven skill levels among participants, putting winning the game lower priority than everyone enjoying the game (DeKoven, 1978). This kind of action is not simply altruistic, but to keep all players' engagement levels high, and thus sharing the mood while going through similar kind of challenges in the game. Comparatively, in remote games among strangers, the goal of shared mood does not seem to be as important as winning the game, as shown in the study on online gamers by Gajadhar et al.: players who won the game reported more engagement and enjoyment than the players who lost (Gajadhar et al., 2008). This comparison between different social play experiences shows how existing social relationships and the medium for interaction affect the ease and importance of synchronizing emotions with other players.

Outcomes of Interaction Ritual

A successful IR leads to individual and group level enjoyment. As an individual, they have more emotional energy (EE) associated with such kind of IR. Players who enjoyed a good game together usually feel their time well spent. They will want to repeat this experience by choosing the game over other methods of entertainment. They will probably prefer to play again with the same group because of the social bond created from the shared game enjoyment last time. These social bonds may turn into stronger social relationships between players. This process of creating and reinforcing social relationships is defined as transformative play by Salen and Zimmerman (Salen & Zimmerman, 2004). A group that has been successful in such game will start to build their identity, especially in highly competitive team-based games, such as teams in MLG (major league gaming).

Summary

In this chapter I introduced IR theory and frame analysis to co-located games to 1) provide a lens for understanding and evaluating social play experience, 2) and generate design guidelines for co-located social games. Analyzing the studies on handheld game console based multiplayer games, board/card games, and console-based co-located games, I adapt IR theory to the domain of co-located gaming, with the perspective of the co-existence and switching between the frames of real world and game world, digital and physical medium. The following table summarizes ways to achieve each of the ingredients in the IR theory, based on the analysis of existing empirical studies through theory-based lens.

Table 7: Theory-based design implications for co-located games

Theory-based Design Implications	
Bodily Presence	**Natural mapping**: Map body movements and gestures naturally to game state changes, e.g., swinging a Wii controller is mapped to swinging a Tennis racket. **Motivating the use of bodily presence in the game:** Encourage players to use their bodily and social skills in the game through the reward system, e.g., players need to pay close attention to others' intonation and facial expressions to win a Mafia game.
The Circle of Play	**Signaling:** Initialize a game through in-game and out-of-game signals, e.g., Nintendo DS players put on buttons to visually indicate that they can potentially join a DS game. **Displaying information to spectators through bodily enacting:** The digital display is not the only way that information is presented. In the social context, the facial expressions and body movements can reveal information trackable to the spectators, e.g., in card games, much tension is shown through the performance of players while their cards are secret.
Mutual Focus of Attention	**Common game object that are independent of players:** Objects that every player can get synchronized to, e.g., the melody in rhythm games. **Shared game objects/activities that are affected by players:** When players interact with the common object or activity, they will have consequential social interactions around them, e.g., solving a shared puzzle can concentrate players' attention to the same goal and they are likely to help each other. **Motivating players to pay attention to each other:** Players can become the common focus of attention, e.g. with the turn-based structure of board games, players take turns to become performers and spectators. When in their turn, players exclusively claim everyone else's attention.
Shared Mood	**Game-generated shared target:** Shared content, cut scene, fun animation, good dialogue can all become the moments that players laugh together. Players may also generate shared mood in the process of going through similar challenges. **Player-generated shared experience:** Players' shared in game and out-of-game experience may evoke similar emotions among players, e.g., commenting on the in-game spot when the players were defeated last time.

CHAPTER 8

THEORY-BASED DESIGN: NERDHERDER

As reported in the previous chapter, theories-based analysis on social play provides design guidelines and implications. However, theories must be embodied in game prototypes to actually impact player behaviors. How do theory-based design guidelines support creating enjoyable social play in HAR games? (RQ3) To answer this question, my team and I designed, implemented, iterated, and evaluated a multiplayer HAR game, *NerdHerder*. It is a multiplayer team based competitive game, in which players control a fishing rod to hook donuts that can be used to feed or entice the game characters. In this game, I choose a subset of the design guidelines from previous chapter based on their relevance to HAR game interfaces and the co-located game scenario. The core game control in *NerdHerder* leveraged players' spatial and physical presence, mapping their physical movements with the camera phone into actions in the digital game world. Moreover, the game mechanics encouraged players to interact with each other, in the digital and physical game space—we introduce dependency between players, direct conflict, and evoke the shared emotion through challenges for teams.

In this chapter, I first briefly introduce the gameplay of the multiplayer *NerdHerder* and the motivations for this game. I then introduce the subset of theory-based guidelines that I choose to adopt for this game, and how they are implemented in this game. Last, I discuss the design process of NerdHerder, include the prototyping, playtesting and iterating the game. The goal of this chapter is to describe how the design process and decisions for one HAR game are affected by both the theory-based implications and our own experience with designing and engineering HAR games. Making the game also yields a prototype that I collect empirical data from by conducting a user study. The study is discussed in detail in the next chapter.

Introduction to the Multiplayer NerdHerder

Motivations

In contrast to the previous two game prototypes (*BragFish* and *ARt of Defense*), multiplayer *NerdHerder* was designed not only based on our experience with HAR interfaces and engineering opportunities, but also theory-based design implications. The goal of NerdHerder is to turn theory-based design guidelines for social games into the end-user experience of co-located gaming, and to find how useful the theory-based design guidelines are. Among the four powers of theory (i.e., descriptive, rhetorical, inferential, and application (Halverson, 2002)), this work leverages the "application" power of sociological theories, applying them to the design of a new HAR multiplayer game.

The game *NerdHerder* is also one of the design artifacts that are generated from the research-through design process. Other than the theory-based design guidelines, my team and I also designed the game based on other threads of research, such as our previous lessons learned from *BragFish* and *AoD* user study and process of design, the affordances and constraints of the HAR interfaces, and the technical opportunities supported by the cutting-edge technology and hardware. Although the focus of this chapter and the next is on theory-based guidelines, how they are implemented and what player behavior emerge as an outcome, the design of *NerdHerder* is based on multiple threads of intellectual and cultural heritage, and the availability of resources and time.

NerdHerder also differentiates itself from *BragFish* and *AoD* by its structure of interaction: players have both cooperative and competitive goals in this game. The team-based competition may introduce new social dynamics between four players that have not been seen in the studies on *BragFish*, a two-player competitive game, and the *AoD*, a two-player cooperative game.

Gameplay of Multiplayer NerdHerder

NerdHerder is a mobile augmented reality game that takes advantage of the player's physical presence in the hybrid game world. Using a HAR interface, the games tracks from a predefined game board and recognizes the real time position of players' camera phones in the 3D coordinate system of the game world. Players use the camera as a window to view the game world overlaid on top of the board and to control digital objects. The core game control is a digital fishing rod that reaches out of each player's camera phone, and uses the fishing hook to collect objects that can affect the movement of game characters.

The multiplayer *NerdHerder* is a 2 vs. 2 team-based competitive HAR game. In the game, the goal is to feed the donuts to the character of the Donut King, who patrols the game board. The team that first gets five points on their scoreboard wins. In the game, players need to use their virtual fishing rod, which is attached to their camera phone, to hook donuts that are scattered on the board and to put them in the mouth of donut king. The donuts spawn periodically. The Donut King occasionally opens his mouth to be fed. When a player successfully feeds him a donut, their team score increases. Two nerds wander around on the board. Each belongs to one team. The nerds are naturally attracted to donuts and moves towards them. The Donut King may step on the nerds and squash them. If this happens, the team associated with the squashed nerd loses one point. There are also power-ups spawning from the game board, including the shaking and stealth power-up. Both of the power-ups can interfere with the other team's action. The shake power-up makes the other team's player's hook randomly jitter for two seconds; while the stealth power-up allows players to sneak up on the other player's hook, and steal their donut. Both power-ups come with an influence range, which requires players to get close to the other person's hook to shake them or steal from them.

Besides the theory-based design considerations, the specific design and aesthetic of multiplayer *NerdHerder* is influenced by cooperative games (e.g., *Left4Dead*), team-based sports (e.g., *Curling*), and board games (e.g., *Hungry Hungry Hippos*).

Figure 20. Screenshots of *NerdHerder* game. In the top picture, the Donut King opened his mouth and players can feed the donut into his mouth; in the bottom picture, the Donut King is in the attack phase and chasing after the Nerds. Players lead the Nerds away from Donut King.

System Configuration

Nerdherder was developed using the Unity game engine combined with Qualcomm's Augmented Reality SDK Unity plugin. The networking between different devices used the PlayerIO Unity API. It was using a Server-Client network structure between the cloud server (provided as a service of PlayerIO) and the phones. One of the players' phones function as an authoritative host that decides the physics and game logic; the rest of the phones function as clients that render data as requested by the host. The server functions as the mailman and passes the data between the clients and the host. If the host player quits the game in the middle of a session, the server will choose one of the remaining phones as a host and continue the game seamlessly.

The game runs on android phones equipped with 1GHz snapdragon processors or higher. It can also be deployed on newer iOS devices such as the iPhone 4S or the iPad2.

Implementations of Theory-based Design Guidelines

In the last chapter, I have adopted and adapted Interaction Ritual Theory and Frame Analysis to the domain of co-located gaming (see Figure 19). I choose a subset of them that are highly relevant to the HAR medium used in the design of *NerdHerder* (see Table 8), and implement them as specific design choices in the multiplayer *NerdHerder*.

Table 8: The subset of chosen design guidelines for *NerdHerder* and their implementations

Chosen Theory-based Design Guidelines for *NerdHerder* and Their Implementations	
Bodily presence	1. **Blending physical and digital game worlds:** Leveraging players' physical movement in the space and skills and experiences of physics. 2. **Constructing the shared awareness by the hybrid co-location:** Using the physical positions of multiple camera views to construct shared awareness among players; Motivating players to observe other's physical position to compensate for the loss of digital information.

Mutual focus of attention	3. **Joining players' attention onto common targets:** Directing players' attention together to the common objects (e.g. shared goals, shared characters) and the activities around these common objects 4. **Dependency on the teammate:** Tuning the game so that it is hard for a player to win by themselves; motivating players to coordinate actions between teammates. 5. **Conflict with the other team:** Causing players to compete against each other around certain objects and timing. The distance-based power-ups are designed for players to pay close attention to others' physical and digital presence.
Shared mood	6. **Shared enemy:** Leveraging the "dramatic anticipation" created in the Donut King's "rage" period, during which he tries to squash the Nerd characters of both teams 7. **Humorous content:** Providing cross-team shared topics to communicate and laugh about

It is worth noting that these are high-level design guidelines targeting social play goals. To make a game enjoyable, designers need to achieve lower-level usability and playability goals. In the design of *NerdHerder*, we also carefully designed and iterated the game mechanics to fulfill usability and playability requirements. For example, to increase the learnability of the game mechanic, we use the "embodied metaphor" of fishing rods as an effective way of conveying the game control to audiences who may not be familiar with AR interfaces. To bridge the gulf of evaluation, we add redundant feedback so that players can perceive the outcome of their actions, which are typically harder to notice with the small display. To support playability goals, we decided not to design puzzles for the multiplayer games, as we wanted to support replayability. Instead, we adopted the rule-based system from sports, and rely on players' skills and social dynamics to provide new challenges for each player.

Blending Physical and Digital Game Worlds

In *NerdHerder*, we create game mechanics that reinforce the feeling that players and game characters and objects exist in the same hybrid space by leveraging the real-time registered graphics of AR. With the constant representation of the fishing rod as part of the game UI, players receive visual and visceral feedback when their physical movements are reflected in the fishing line, consequently influencing game characters.

The fishing line and lure are dangling from the fishing rod, giving players control of game characters. This game control is a challenge on its own for players to master (Juul & Norton, 2009) and it requires physical skills of precision and timing-control. It is tied with the real-world physics of how a fishing line is expected to work, leveraging players' existing knowledge and skills.

Handheld AR interfaces also enable players to combine first-person and third-person perspectives. With the top-down view enabled by the trackable boards placed on a table surface, we allow players to act as a "god" player in the game. At the same time, players are part of the game; their movement is directly mapped to the change of game state, which is a first-person gaming convention. The persistent fishing rod is also a reminder of the first-person presence. By leveraging mobile AR interfaces, we seamlessly integrate first-person and third-person presence in the game.

In the context of multiplayer games, this natural mapping between players' actions in the physical world and their in-game representations (i.e., the hook attached to the camera phone), these actions enables players to infer other players game state based on their physical positions and movements. Moreover, the physical game board serves as a shared coordinate system where virtual objects are spawned and move around. Players can understand where the virtual objects' positions are in relation to other players based on this shared 3D coordinate system that blends the digital and physical components of the game together. When players coordinate their actions in relation to others, they can have a reasonable prediction of other players' and game characters' movements and timing in relation to theirs.

Motivating Players to Leverage the Hybrid Co-location

Co-location of players in the physical space does not guarantee a game will be played socially (Szentgyorgyi et al., 2008), but it does provide a higher fidelity, faster feedback loop, and richer communication channel between players (Collins, 2004). We design multiplayer *NerdHerder* to motivate players by leveraging their co-presence in the shared hybrid space.

HAR interfaces allow players to physically control the camera through which the digital world is viewed. In multiplayer games, this feature is critical for players' communication for constructing shared awareness. In the research of (Voida et al., 2010) and (Seif El-Nasr, 2010) of playing console games together, both found that how players control their camera contribute to how they communicate and interact with each other. Because console games often have split screens or avatar-following cameras, multiple players may see different objects and scenes on their screen at the same time. Through communicating with each other the group construct a shared awareness of the digital presence of their in-game representations. In contrast, in the game of *NerdHerder* that leverage a HAR interface, players may only see a fraction of the game world because of the small display of handheld devices, but they can stich together a bigger picture due to their awareness of each other's camera position in the physical world, which is the same as their positions in the digital world.

Other than leveraging the physical positions of camera phones, we designed game mechanics that motivate players to pay attention to other players' physical positions and movements. Both kinds of the power-ups in the game, including the "shake" and "stealth", require players' hooks to be in proximity to take effect. Therefore, players need to pay attention to others' in-game representations. Moreover, the "stealth" power-up was designed to encourage players to pay attention to others' physical co-presence. When a player gets the "stealth" power-up, they become invisible for 5 seconds, during which this player can steal donuts from others by getting close to them. While the other players have lost the ability to see the player digitally, they still can observe them in the physical world and try to avoid getting close to them to prevent their donuts getting stolen. The "stealth" power-up was designed to leverage both digital co-presence (i.e. to keep track of who activated the power-ups and when) and physically (i.e. to avoid being affected negatively by another's power-up by observing their physical position and movements).

Join Players' Attention onto Common Targets

The previous two design rationales are based on the "bodily presence" ingredient in the IR theory, whereas the following three are about supporting "mutual focus of attention" through different game mechanics. In the last chapter, I discussed three ways of joining players' attention in game design practices. Here I use common objects that players can change the state of to again join their attention.

On top of the shared hybrid space (the physical game board and the digital world registered on it), we designed for a "shared goal" and "shared characters" to gather players' attention. Between the teammates, they share the same goal of feeding the donut king and protecting the nerd. The performance of both players are added and displayed on the scoreboard; the individual contribution to the score is not shown until the end of the game. Both of the players can interact with the nerd using donuts. If their Nerd character gets squashed by the Donut King, the team loses one point. Between the teams, they share the same area for scoring the donut—above the Donut King's open mouth. Players can also lead the other team's nerd around using the donut, thus they can strategize to spend their time and attention on defending or attacking.

These shared goals and characters provide common targets that players are motivated to pay attention to. Moreover, to fight for these objects, players continue to pay attention to each other regarding the activities around these objects, whether it is through the coordination between teammate or the competition between the two teams. Since both the Donut King and Nerds are moving on the game board, players also need to move themselves to physically get closer to or further away from these objects. Players can observe each other and be aware of other players' attention being focused on the same object and activity by their in-game representation's movements or their own physical movements.

Dependency on the Teammate

As discussed in the previous chapter, one way to support a mutual focus of attention is to encourage players to take turns, and therefore to focus their attention on other players sequentially. This kind of design is most common in board/card games, where the turn-based structure is both a necessity that is decided by the paper medium and a structure that fosters players exclusively claiming each other's attention when it is their turn. In the design of the multiplayer *NerdHerder*, we tuned the game so that it is hard for one player to win by focusing only on themselves, instead, they need to coordinate with their teammate to share the multiple tasks required for winning. This design was inspired by multiplayer sports such as curling, where players need to work on different tasks to win the game together. However, in Nerderder, the collaboration required between players is more synchronous and dynamic than the sport of curling.

Specifically, we create a multitasking challenge where a team needs to feed the Donut King, while making sure that Donut King does not step on the Nerds. We initially put in these two goals in parallel; players could choose which task they want to focus on. In this iteration, the Donut King and Nerds were wandering around, and the Donut King ran into the Nerds randomly, each time taking a point from their team. During the playtesting, we found that players prefer the task of feeding the Donut King rather than leading the nerd. They also has little coordination between teammates; each of the players was focusing on feeding on the Donut King, hardly noticing that they were losing points from the nerds being stepped on. In the next iteration of the game we made design changes to address this issue by separating the tasks of feeding the Donut King and leading the nerds into different phases. The Donut King now closes his mouth when he is fed four times in a row. Then he will stop moving, makes a roaring sound, stomps twice, pauses for four seconds, and then charges directly at the nerds. By separating the two tasks and announcing the attacking phase clearly to players, we allow players to anticipate what is about the happen and also have time to coordinate their next action together. Previously the Donut King only ran into the Nerds when their paths randomly crossed, however, in the new design with the charging phase, the Nerds will be squashed for sure if the players do not try to lead them away. This increases the importance of for communication and coordination between players for multitasking.

Conflict with the Opponent Team

Similar to the motivation of the previous design rationale, this design is intended for encouraging players to keep track of their opponent teams. A competitive game does not necessarily need to involve direct conflicts. For example, in *BragFish*, players can choose to have minimum amount of conflict with each other; they can play in parallel, whoever catches a certain amount and type of fish wins. This kind of score-system based competition is common in many sports, such as swimming and track-and-field. However, in *NerdHerder*, our goal is to encourage players' to interact with each other. Therefore, we put in game mechanics that players need to come into conflict with each other and pay attention to their opponents' actions.

First, we designed the power-ups to introduce direct conflict between opposing teams. The power-ups are distance based, meaning that players need to intentionally chase after the opposing players' hook. We also make sure that the maximum number of donuts on the game board (including those already hooked) is three, so that at least one of the players is motivated to search for power-ups and use it on other players. This is related to the second design rationale where we encourage players to actively use their co-presence in the physical-digital space to use or avoid the power-ups. This game mechanics is designed to achieve the goal of gathering players' attention on one of the players and their in-game representations.

Second, we allow players to fight over the Nerd characters. The Nerds are responsive to any donut, including donuts hooked by the opposing team. In this case, the Nerds become a common object that players have mutual focus of attention on.

Shared Enemy

Besides the shared emotion between teammates, we experiment with creating more opportunities for the four-person group to share their mood. We designed the Donut King's "rage" behavior to achieve this goal.

In the game, the Donut King chases after the Nerd characters one by one. Both teams have an equal chance of their Nerd characters being squashed and making a scared sound. When this happens, the team loses one point. Since the Donut King's "rage" phase concentrates on squashing the Nerds, players face the same enemy during that period. We also increased the difficulty of defending against the Donut King so that players may lose their Nerds to the Donut King a few times before they learn the skills of observing the path of the charging Donut King and quickly move their nerd out of the way.

Before the Donut King launches the "rage" period, we intentionally leave players a few seconds before the attack, increasing the "dramatic anticipation" among all players. The term of "dramatic anticipation" was brought forward by game designers of Left4Dead, referring to a powerful design pattern of setting up moments where one event may lead to another interesting event by leveraging players' anticipation (Booth, 2009). This has been proven to be effective in their design of online cooperative games, especially for creating the shared fear among players in the Left4Dead. In our design, we also leverage similar game mechanic to emphasize the shared mood across teams.

Humorous Content

As discussed earlier, game-related content, such as cut scenes, animation, narratives, is likely to trigger shared mood among players, especially shared laughter. In the multiplayer *NerdHerder*, we tap into the nerd culture and creative cartoony styles of animations and sound design. The goal of the humorous content is to provide common topics for players to talk and laugh about across the team division.

Design and Implementation Process

Design and Development Team

NerdHerder is a cross-institute collaborative project. The team members came from three institutes, including Interactive Computing School in Georgia Institute of Technology, Interactive Design and Game Development in Savannah College and Art Design, and Berklee College of Music. The cross-institute collaboration is encouraged in the Handheld Augmented Reality Studio hosted by the Augmented Environments Lab in Georgia Tech, and funded by Qualcomm.

We also receive valuable expert feedback and suggestions from our instructors, including Dr. Blair MacIntyre and Dr. John Sharp. Their comments are discussed and evaluated based on the results of playtesting and our own time constraints.

Playtesting-Iteration Loops

The design and development process of *NerdHerder* is highly iterative. The timeline of the project is shown in the following Figure 21. We not only playtest frequently with players we have access to in our daily environment, but also actively seek professional feedback and comments from the game design, augmented reality, and HCI communities. Testing and demoing the game with a broad audience helped us to gain external validity of the design and provided valuable feedback to improve it.

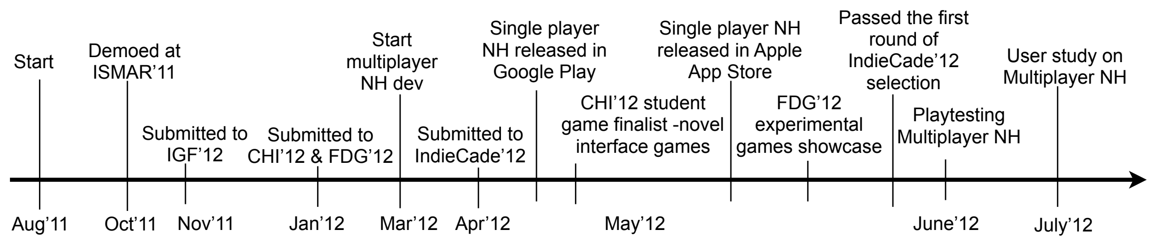


Figure 21. The timeline of major events for *NerdHerder* development

We demonstrated different versions of the game repeatedly in the past year, most recently to over 50 users at the International Symposium of Mixed and Augmented Reality (ISMAR'11), around 20 users at Georgia Tech's Future Media 2011, 40-50 users during ACM CHI 2012, and 20-30 users during ACM FDG (Foundations for Digital Games) 2012.

Figure 22. Playtesting with high-school kids from a summer camp

My team and I have also conducted frequent playtesting with various audiences, including our friends and colleagues, we have gone to undergrad and grad classes in Georgia Tech and Savannah College of Art and Design, Atlanta Game Developer Meetup, summer camps, and even coffee shops to ask people to help us testing the game. Some of the testing sessions are shorter, with more specific goals achievable in that time frame, such as tutorial on the basic game mechanics. Some of them are longer, requiring a chunk of time from our users to engage in the gameplay. For the multiplayer game, we have tested the game with our friends for several rounds, and we went to the summer camp for high-school students to test out the game.

Although playtesting could be emotionally challenging even for expert designers (i.e., Jesse Schell in his book admitted that he dislikes playtesting the most in game design process (Schell, 2008)), especially when testing your own game. But we found that it is also fruitful, revealing the problems that we would not be able to see as an expert user of AR interfaces. With each playtesting, we generated a task lists that has around 10-30 problems to solve and developed solutions to each of them through group discussion. We also found that solutions to existing problems may introduce new problems. That's why our iterations were done in a agile and frequent style (see Figure 23). We addressed several significant design problems that were critical to the quality of gameplay, which are discussed in the section below.

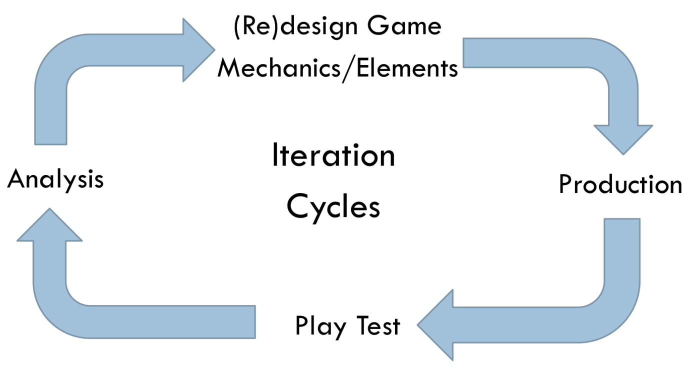


Figure 23. Each step in cycles of iteration during *NerdHerder* development

Design Challenges

Searching for Intuitive and Satisfying Interactions

The physical actions supported by a mobile AR interface are the basis for the core game mechanics. Through significant iteration and playtesting, we found the following two criteria are critical for physical action based games: 1) natural mapping between players' physical movements and the responses that game characters and environment give; 2) continuously satisfying play. This second point turns out to be critical: because the core game mechanics exist throughout the game, and physical actions can be tiring, it is critical to make sure the ongoing activities of the player are satisfying rather than repetitive or tedious. To achieve these goals, we evolved three different game mechanics.

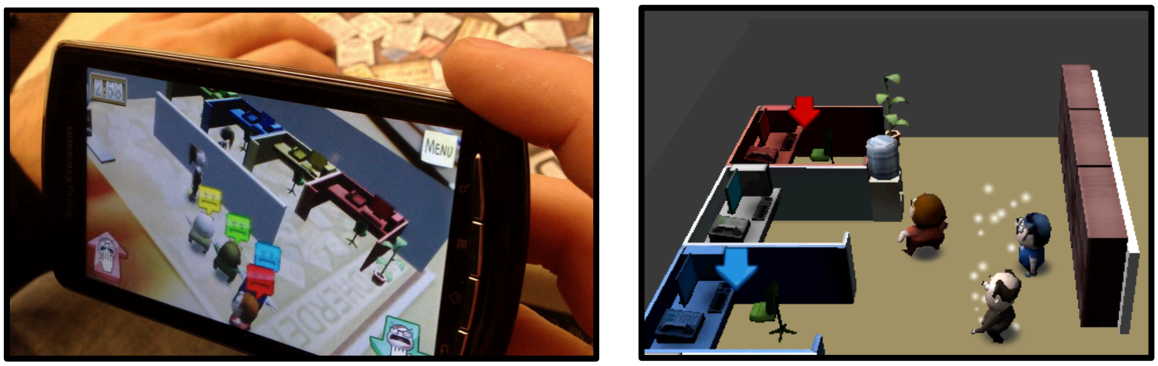


Figure 24. (Left). *NerdHerder* iteration 1 (with push-and-pull mechanics); (Right). *NerdHerder* iteration 2 (with the holodeck characters teleporting)

The first game mechanic we developed is a push-and-pull, directly using the camera position in relation to the game character (Figure 24(left)). This interaction, referred to as "Hands-on Management style", requires players to get within a certain distance to the game character to affect them. This mechanic was designed to encourage players to physically move around the board, and also move closer to or further from the game board. However, we discovered two problems from playtesting. First, players do not know what to do when they first see the game (*gulf of execution* (Norman, 1988)). For example, players do not know that they need to get close enough to influence the Nerd characters. Second, this interaction becomes tedious because players tend to stay close to the board all the time and forget to draw back and get a bigger picture to solve the puzzles (and enjoy the aesthetics of the experience). While the first problem can be overcome through tutorials, the second problem is inherent in the mechanic: by allowing the player to affect the Nerds from further away, the player loses the ability to meaningfully control them as their actions are imprecise.

The second technique we have tried is the “remote hologram” concept, where the player controls an imaginary hologram of the boss that is teleported into the office world by aiming at the game board and launching actions (Figure 24(Right)). This mechanic, referred to as “Art of Delegation”, allows players to precisely control the position of hologram characters. We found the following problems through playtesting. First, players stop moving around in the physical world, and assume a viewpoint that allows them to see and control the entire game board. There is no motivation for them to move around the board. Second, this interaction is not particularly innovative: in practice, it feels very similar to the point-and-shoot mechanic that has been implemented in many existing mobile AR games.

To solve the above problems, we created a third mechanic: a virtual fishing rod. By attaching a fishing pole to the camera, we allow players to repel or attract the players depending on the objects they use on the hook (Figure 20). This mechanic, referred to as “Carrot-and-Stick”, leverages physical movements by hovering on top of the game board. It solves the problem of players not knowing what to do by rendering the player’s real-time position in relation to the board by the fishing rod and the shadow it projects. It also requires players to move around the board rather than simply tilting their device.

Novice vs. Expert Users

During the demos we encouraged players to experiment with the game and observed differences between novice and expert AR interface users, as well as people who consider themselves as gamers and non-gamers.

Novice AR interface users tend to hold the device still and sometimes even get stiff. They are more comfortable using existing interaction conventions on mobile phones, such as touch screen. To mitigate this we include a tutorial for players unfamiliar with

AR interfaces. When testing with users who consider themselves gamers, sometimes their expectations do not work to our advantage. For example, one user did not understand the concept of “the player is the controller”, but instead believed that the characters (nerds) were his avatar(s). To solve this problem, we also provide tutorials that scaffold the learning of AR-based game mechanics. These tutorials were designed through a combination of usability inspection methods and storyboarding used in discussions with Augmented Reality experts, as well as analysis of game testers.

Summary

The design of the multiplayer *NerdHerder* embodies the theory-based design guidelines generated in chapter 7. We chose to implement seven of them depending on their relevance to Handheld AR games. To encourage players to leverage their bodily presence during the gameplay, we design the game control and visualization to blend the digital and physical worlds. We also motivate players to leverage their hybrid co-presence to construct a shared awareness. To join players’ attention and increase their awareness of other players’ actions and states, we designed the common objects that all players can act upon, increased the dependency between teammates, and intensified the conflict between players. To support players’ sharing and synchronizing emotions, we designed the game character of the Donut King to be a shared enemy that evokes similar kind of emotions and reactions among all players. The humorous game content also supports generating shared emotion by providing a light-hearted atmosphere and shared conversational topics for the group.

Other than the design guidelines that are integrated in the game, the team’s knowledge and experience with HAR interface, engineering efforts, player-centric iterations all contribute to the final prototype. In the next chapter, I am going to focus on the user study on *NerdHerder*. The empirical findings show how the game was played by groups of participants, their emergent social behaviors, and how game design elements support and trigger such behaviors.

CHAPTER 9

USER STUDY ON NERDHERDER

Both this chapter and the previous one aim to address research question 3, "How do theory-based design guidelines support creating enjoyable social play in HAR games?" While the last chapter focused on how the HAR game prototype of *NerdHerder* was designed based on the theory-based design guidelines, this chapter reports on the user study that collected and analyzed empirical data of social play behavior during the gameplay. The goal of the user study is to understand the outcome of the theory-based design guidelines and their implementations in *NerdHerder*. Specifically, what kind of social play behaviors emerge, how these behaviors are associated with the design considerations, and what role the reality-based interface of HAR plays in this kind of player experience.

Note that the goal of the study is not to prove or disprove the related sociological theories that I drew design implications from. Instead, the role of theory is "*provisional, contingent, and aspirational*" (Gaver, 2012). The role of the theories in my work is to generalize the particular design choices made for one game, to provide a language to describe the phenomenon, and to open up design spaces that can generate a rich set of design examples.

This chapter starts with the study design, which is guided by the sub-questions raised for answering research question 3. Then I report the findings from the study, connecting the empirical data with design considerations we integrate in *NerdHerder*. I end the chapter with a discussion on how the elements of social interaction can be supported and reshaped by the affordances of game interfaces through design.

Study Design

The design of the user study is first and foremost decided by the research question that it addresses. To answer research question 3, I break it down into three sub-questions:

1. What kind of social play behaviors emerge from playing *NerdHerder*, a design instance that embodies some of the theory-based design implications?
2. How are the social play behaviors supported and triggered by each of the design guidelines embedded in the game?
3. What is the role of reality-based interfaces (i.e., Handheld Augmented Reality) in supporting these social play behaviors in the shared hybrid space?

The first question can be answered through observing and video recording gameplay sessions. The data analysis needs to focus on the events that involve interpersonal interactions and communications. The second and third sub-question is beyond "what" happens, to "how" and "why" it happens. Therefore, it is important to sequentially analyze the game log to find what game event precedes or occurs together with certain player behaviors. The interview data is also important for answering "why" questions based on players' reflection on their own experience.

Because answering these questions requires capturing the gameplay sessions in great detail from multiple perspectives, and because

Procedure and Setting

The user study included four parts. *First*, the participants filled out a player demographics questionnaire after they viewed and signed the consent forms. *Second*, the players learned the game, including the game control mechanics and multiplayer game rules. To learn the game every player first went through the tutorial that we designed for casual players to familiarize themselves with AR interfaces. A researcher walked players through the tutorial and answered questions, making sure that every participant finish and had practice with the game controls. The participants then learned the basic game mechanics of hooking a donut using the virtual fishing rod that reaches out from their camera and using the donut to lure the nerds by trying the first two levels of the single player *NerdHerder*. After they got used to the game mechanics, participants started to play the multiplayer *NerdHerder*. During a trial session, the researcher introduced the goal, each of the game characters and their interactions, the team score system, and the power-ups. Players were encouraged to ask questions and the researcher answered them. The researcher prepared a list of the key points about the game control and rules beforehand, and made sure that they were all mentioned during the learning and trial session. *Third*, after everyone agreed that they understood the game, they played the multiplayer game twice. The game sessions were video recorded and the game logs (including event data and sampled position data) were recorded on the device. The researcher took observational notes while the game was played. *Finally*, the participants filled out two questionnaires about social presence and game experience after playing the game. Following the games a semi-structured interview was conducted to understand more about the incentives and experience.

The user study was set up in a research lab. The four participants could choose where they stood around a round table (*diameter* = 36"). On the table was the square-shape game board (*width* = 22"). To capture and synchronize the video of play behavior and game events, I set up four cameras. Two cameras were hung at a height of 7', at opposite sides of the table and tilted down (See Figure 25 & 26, Camera 2 and 3). These two cameras were set to capture the facial expression of players. A top down camera was placed at a height of 9' above the table to capture players' movements in the space (See Figure 25 & 26, Camera 1). The video was composed together using Quatzcomposer (a video composing software that runs on Mac OSX) and captured using Mac OSX built in screen capture function. A fourth camera was placed 6' away from the center of the board at the height of 4.6', giving a side view of the scene (See Figure 25 & 26, Camera 4). This was used as a back-up camera, and was connected to a different computer.

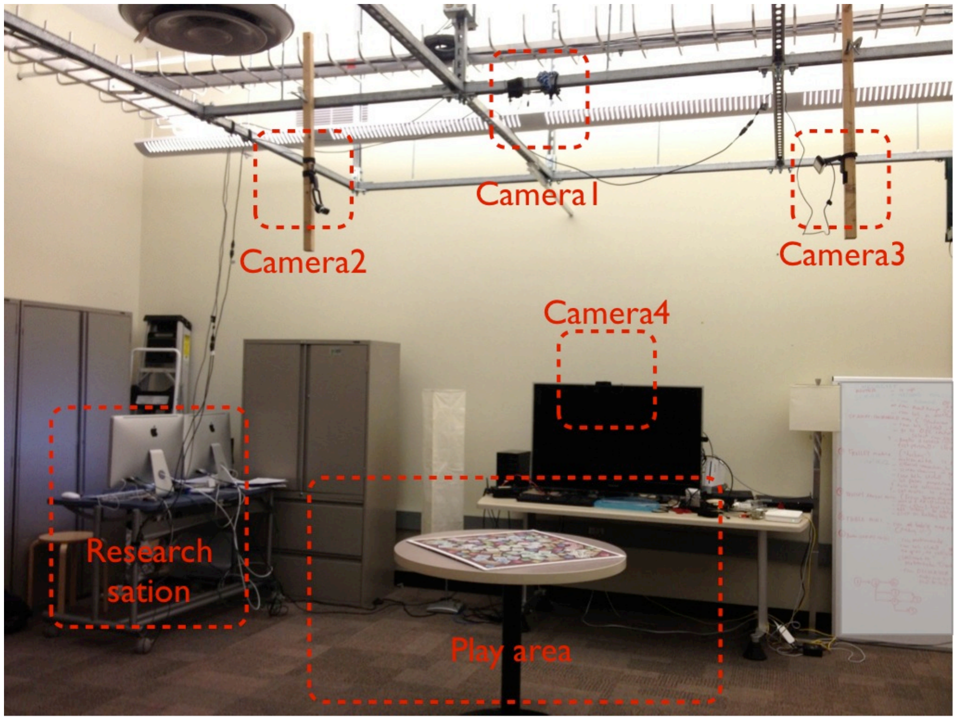


Figure 25. The overview of the user study setting

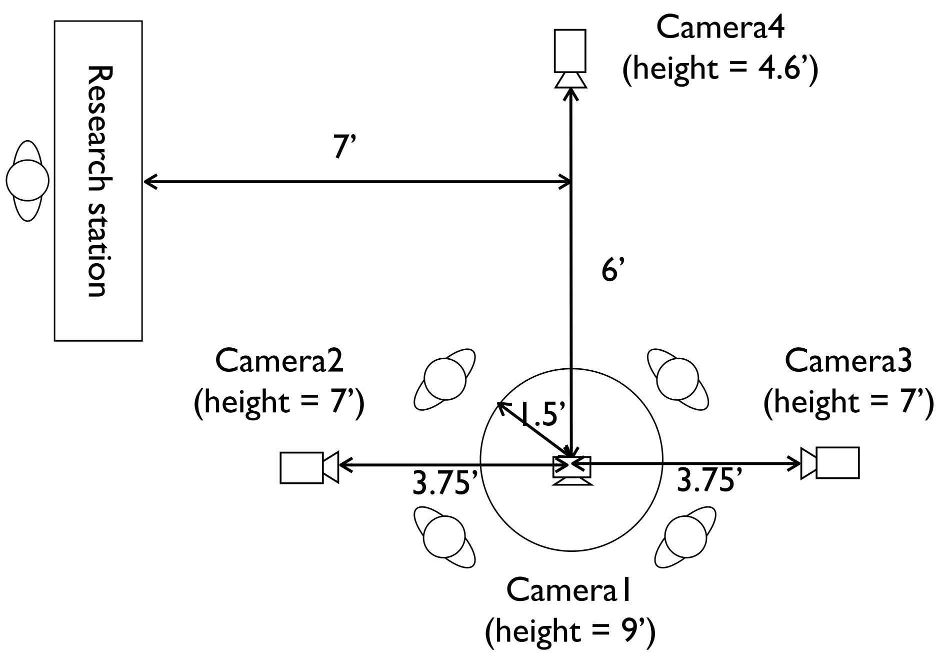


Figure 26. The configuration of the user study setting (top down view)

Data Collection

The recorded video synchronized the game screens with the top-down videos that captured the physical movements of both players. With this data, we were able to reconstruct what went on during game play, how the players moved and the problems they encountered. In addition, one researcher took observational notes during the game play, to record interesting moments of play and to generate related questions for the interview.

Questionnaires

Before the game the players entered their demographic information and gameplay history in a questionnaire (See Appendix E).

After the game sessions, the participants were given two questionnaires to fill in: a social presence questionnaire (adapted from (Biocca et al., 2003; De Kort & Ijsselsteijn, 2008)) (See Appendix C) and a game experience questionnaire (See Appendix D). We used cross-checking questions to address the problem of misreporting.

Direct observation

During the gameplay, a researcher sat at the research station where she can observe the player behaviors and interactions. This station was where the camera videos were displayed and captured, and was set approximately 7' away from the play area. The researcher tried to be unobtrusive to the gameplay, watching rather than taking part in the gameplay. The only interactions she had with the participants during the gameplay were answering the questions that were explicitly directed to her.

The researcher made observational notes during the game sessions, which focused on inter-personal behaviors, with the following questions to address in mind: What kind of social interaction did players have during the game? What did they verbally communicate about? How did players move themselves in relation to each other? When players burst into shared laughter and move, what triggered it? The observation is assisted by a reminder list of observable social interaction behaviors (Appendix A).

A Semi-structured Interview

At the end of the user study, we conducted a semi-structured interview. While the observation and video focused on finding behavioral patterns, the interview focused on understanding the subjective experience of the players, including the strategies they adopted, their awareness of the other players, and the comparison between this game and other games they had played before. The prepared interview questions are included in Appendix B.

Game Log

One of the difficulties of researching mobile games is keeping track of what is occurring for each of the players on their small screen. Having video out cables (as we did in *ARt of Defense*) limits the mobility of the players. In games where players sit around a table it is less of an issue because the cable is long enough for hand and arm movements. However, in *NerdHerder* we set up the game to be played among standing and moving players. The mobility of the game ruled out the option of using cables to capture on-screen events. Hence, to solve this problem, we instead recorded game events and sampled game data. The game events data include: Win/lose the game, donuts spawning, A Nerd being knocked over by the Donut King, power-ups spawning, getting power-ups, and using the power-ups on the other player(s). The sampled data include: the camera position, the hooks' positions, the Donut King and Nerds' positions. The sampling rate was 2 frames per second. All the event and sampled data were time stamped for the purpose of being synchronized with the video of gameplay.

Using the recorded game log data, we can trace what happened before and at the moment of user behaviors captured in the video, which is used to understand the trigger for interpersonal social behaviors.

Data Analysis

"*How one approaches an analysis depends crucially on one's theoretical commitments, the specific research questions one is pursuing, and the practical constraints of time, money, and personnel*." (Derry, 2007) The data analysis of *NerdHerder* is first and foremost guided by the research questions raised at the beginning of this chapter.

The core data for analysis are gameplay sessions and interviews. The interpretation of the data is assisted by the game log (synchronized by the timestamps) and the feedback survey. The analysis went through several iterations, following the video analysis guide by Derry et al. (Derry, 2007) The *first* round was inductive analysis on participants' interpersonal behaviors during the game. In this phase, the goal was to index and identify all the occasions of social interactions and social play. Using the ExpressScribe Pro software, I extracted "events" from the videos of gameplay sessions and indexed them by timestamps (Goldman et al., 2007). The events were selected based on the following criteria: 1) Interpersonal, the events involving more than one player's participation, including initializing and responding actions; 2) Involving communicative actions and interactions, such as verbal conversations, non-verbal utterance, burst of emotions, gestures, and movements; and 3) Recognizable beginnings and endings (Ash, 2007). The purpose of step one is to index the data and focus the scope of analysis on selected social events to prepare for further interpretation. Psychological studies show that people can "see" events similarly, including the causal, behavioral, and thematic structures aspects of events, but experts can interpret the events in a greater depth (Goodwin, 1994, 1995).

The second step of the analysis was to cluster the events. To gain more flexibility, the events were summarized and written on post-its. This method was inspired by affinity diagram (Beyer & Holtzblatt, 1997). Each post-it included the information about what happened and what lead to/supported such behaviors. They were numbered with the group ID, play session, and the time order when it happened in that play session. Recording both the behavior and the game design that may lead to these behaviors has been shown to be informative in game design research (Seif El-Nasr, 2010). With the post-its, the events were clusters by their similarity to each other. This step turned the sequential video clips into data that showed the frequency of each kind of social event in the whole data set (Figure 27).

Figure 27. The clustered post-its extracted from video analysis: the longest five lines (the most frequent events) were: collaboration (e.g. coordinating multiple takes, helping others and discussion of strategy), calling out game state changes (e.g., danger to the team's Nerd, score changes, donuts being stolen), collaborative learning (e.g., commenting on the game AI (artificial intelligence) for characters and experimenting with the physics and viewing angle), competition (e.g., trash talking, movement, trying to control the same game character), and frustration and comments triggered by the Donut King crashing the nerds.

The *third* step reexamined the data through the lens of the design guidelines. In step 2, I determined which the design elements and game state change triggered and supported the play behaviors that emerged. The third step organized user behaviors that correspond to each of the seven theory-based design guidelines summarized in the last chapter. For each of the implementations of the design guidelines, I report the interpersonal behaviors that were triggered or supported by the design, the challenges players encountered, and the emergent behaviors that were unexpected.

The data analysis method has the limit of relying on one researcher's analysis. This subjectivity was mostly introduced in the second phases of this analysis. In the phase of clustering the events, the same event could be interpreted in different ways. For example, a player calling out for help can be categorized as both a collaborative behavior and verbal communication, depending on the research focus and the researcher's familiarity with the topic. This subjectivity, although impossible to eliminate for qualitative research, can be reduced by involving independent researchers in the data analysis process to increase the reliability of this work (Hinds et al., 1990).

Player demographics

In total, eight groups of four players (32) joined the user study. They were recruited through fliers, word-of-mouth, and mailing lists. Among the 32 participants, 9 (28.1%) were female; the average age was 21.7 (*Min* = 16; *Max* = 38; *SD* = 5.4); 5

(15.6%) had experience with augmented reality interfaces prior to the user study. All of them had played games with certain kind of reality-based of interface before. Wii games were the most frequently mentioned category. The median weekly game time was 5.0 hours (*Min* = 0; *Max* = 60; *Mean* = 10.2; *SD* = 16.2). Two participants reported 60 hours of gaming in a week. For the rest of the 30 participants, their median weekly game time was 4.0 hours, with an average of 5.9 hours. Players choose what kind of gamer they think themselves are, including 5 hard core gamer, 13 casual player, 7 in-between hard core and casual player, and 7 non-gamer.

Group composition

Prior work has shown that the existing social relationships among players affect their enjoyment playing a game. During social interactions, people tend to be more expressive in the presence of a friend than in the presence of a stranger (Wagner & Smith, 1991). Moreover, players tend to more engaged when playing against a human companions than against a computer (Mandryk & Inkpen, 2004). In the previous study with *BragFish*, I observed very different group dynamics between friends and strangers; the interaction between strangers seemed to be more "polite" and conflict aversive. In the four-player (2 vs. 2) game of *NerdHerder*, I requested all participants to bring either one or three friends with them to the user study. This requirement was intended to ensure everyone came with someone they already knew. All players showed up in teams of two or four except Group 4 and 7. In Group 4, a third friend came along with a 2-person pair. I included the third participant by rotating the participants in the game, allowing two of the friends to play while the one extra person became a spectator. Group7 was scheduled to have two groups of friends. However, one group brought a third friend, the other group happened to be missing one person due to a last minute emergency. The four participants in Group 7 were around the same age (17-19) and mingled with each other before they started the game.

During the user study, players were told to choose whomever they wanted to team up with, not necessarily the friend they already knew before the game. They were also free to choose where to stand or move around the table.

Table 9: The group composition and social relationships among participants

Group ID	Female/ Total	Social Relationships Among Participants in Each Group
1	0/4	A group of classmates from the same class
2	2/4	Two pairs of friends. One pair is made of friends since elementary school; the other pair includes two roommates from the undergraduate student dormitory.
3	0/4	A group of friends from the same church. Two of them share the same occupation.
4	1/5	Two groups of friends. One group is made of lab mates in grad school; the other group includes three summer interns who are on the second year of high school.
5	1/4	Two pairs of friends. One group is made of grad school friends; the other group includes two roommates from the undergraduate student dormitory.
6	2/4	A group of friends who all come from the same university in another state. They are in Atlanta for the same summer intern program. This group lives in the same building during the summer.
7	0/4	Three participants are long-term friends who just graduated from high school together. One undergrad student who was scheduled to come together with his friend. But his friend did not show up because of last-minute emergency.
8	3/4	Two pairs of friends. One pair is made of friends met in grad school; the other pair includes two sisters.

In the following sections, I referred to the participants in the format of their group number and player ID. For example, G1P1 means player 1 in the first group. In quotes when players mentioned others by the names, I replace the real names with pseudonyms.

Findings

Overview of Player Experience and Social Play

The user study of the multiplayer *NerdHerder* yielded a variety of social dynamics and interactions. On a 1-7 likert scale, the average game enjoyment was 5.94

(*SD* = 1.41). Players enjoyed social interactions during the game (*mean* = 5.94, *SD* = 1.25).

Participants compared *NerdHerder* game experience with other co-located games they had during the interview. Since all the participants had experience with games with reality-based interfaces before, they tended to compare *NerdHerder* with other movement-based games (G1P1, G1P2, G3P1, G3P2, G3P4, G6P2, G6P3, G8P1, G8P2). Participants considered *NerdHerder* to be equally social or more social than those other games. For example, in the following example, G7P2 compared the social interactions in *NerdHerder* with her past experience with Dance Central on Xbox Kinect,

> *G7P2: This (NerdHerder) was more social. I don't talk to my sister while we are dancing. At the end, we are like, oh, look at your picture…oh, whatever, you know... If you heard us [during the game], we were talking, "oh nerd, move away...", we were all laughing...*

Some players compared *NerdHerder* with sports games (G7P1, G2P3) and felt similar kind of excitement. In the following quote, G7P1 compared *NerdHerder* with a Wii sports game.

> *G7P1: I usually play basketball games. My brother and my cousins are really into it, like on the Wii...I can take from here (NerdHerder gameplay) all the hype from NBA game the same, even though it's a sports game… it could be strategy or fun. It was still the same excitement even though the games are kind of different.*
> *Interviewer: What do you mean by the 'excitement' and 'hype'?*
> *G7P1: Right, you are running, and you are guarding other players, you're shooting, you want it to go in and so you are like rooting for it. So it's sort of the same thing here even though that's a different kind of game.*

Some other players compared *NerdHerder* with online first person shooter games. The ease of learning the game control (G2P1) and the cartoony theme of the game (G7P2, G7P4) made it more relaxing and causal, and generated a higher amount of social interactions (G6P3). Some commented that the online FPS games incorporated more well-planned teamwork than *NerdHerder* (G4P1, G4P5, G7P1).

Players attributed the sociable gameplay of *NerdHerder* to the "physical movement" (G3P2, G2P3, G5P4), "more intimate setting" (G1P1, G2P3), "communication" (G5P4), "casual gameplay" (G2P1, G7P2, G7P4), and "collaboration" (G2P2, G2P3).

> *G5P4: I like it from a social aspect, because, one, there is a lot of movement; two, there is a lot interaction with other people, as opposed to some sort of board game, which is slow pace. You have to wait for the dice, or the turn-based system. Everybody is facing each other, and playing at the same time, and communicating, so I think it adds a lot more social value than a lot of things where everybody is, even if you have a four player game on a PlayStation, something that everybody is looking at the screen and focusing on that, whereas everybody is facing each other. And you know, just the positioning and the communication, adds a lot of values to the social, in my opinion.*

In summary, *NerdHerder* provided a social and enjoyable game experience for most players. While the above examples and quotes showed the subjective and self-reported player experience, the following sections focus on the video analysis of the game sessions and provide a detailed picture of how players interacted with the game and with other players.

Player Behaviors Associated with the Theory-based Design Guidelines

This section presents the players' emergent social behaviors that were supported or triggered by the implementations of theory-based design guidelines. The goal of this section is to illustrate the connection between design elements and players' inter-personal interactions, as the following table summarizes. For player behaviors that are unexpected and not associated with our previous design considerations, I discuss them in the end of this section.

Table 10: Summary of players' behaviors supported by the implementations of the theory-based design guidelines

Players' behaviors supported by the implementations of the theory-based design guidelines	
Bodily presence	8. **Blending physical and digital game worlds:** This supports learnability and ease-of-use. Players used the shared coordinate system between digital and physical spaces and physics-related skills for cooperative and competitive play. 9. **Constructing shared awareness through hybrid co-location:** Players constructed shared awareness through 1) verbal communication, 2) non-speech sound, 3) observation of on-screen events, and 4) physical movements. The imprecise mapping between the physical position of the camera phone and the digital position of the hook was a challenge for people to infer the avatar's in-game position from the players' physical position.
Mutual focus of attention	10. **Joining players' attention with common objects:** The shared goal and characters provided players shared targets that they all paid attention to and changed the state of. Collaborative learning, teamwork, and head-to-head competition happened around these common objects. 11. **Dependency on the teammate:** This triggered behaviors such as suggesting and coordinating actions, helping with resources and information, emotional exchange and sharing. 12. **Conflict with the opponent team:** the direct conflicts we introduced between teams generated physical movements, trash talking, and bursts of emotion. The in-game competition was juxtaposed with real-world relationships, showing players' switch between the frames of "game" and "everyday life."
Shared mood	13. **Shared enemy:** The shared enemy brought out the shared mood of frustration among all players. In one group, the two teams changed the game to be collaborative to win over the shared enemy. 14. **Funny content:** Providing shared topics to communicate and joke about.

Blending Physical and Digital Game Worlds

We designed the core game control to be the fishing rod and hook that reach out from the camera phone. On a 1-7 likert scale, the survey showed that players considered this game control to be intuitive (*mean* = 5.30, *SD* = 1.36) and easy to learn (*mean* = 5.95, *SD* = 1.06). During the interview, players attributed the learnability and ease of use to the first-person top down perspective, which visually aligns the coordinate system of the digital game world with the physical world. Players also leveraged their natural skills of physics in the game, such as predicting the movement of the dangling fishing hook and calculating the time for moving between two locations.

In the multiplayer scenarios, I observed that players used the reference system in the physical world to interact with digital content in both cooperative and competitive situations. For example, players in several groups pointed out certain positions on the physical game board to show their teammate where the resources were, indicating that players understood the overlapped coordinate system for the digital and physical spaces (as shown in the Figure 28).

Figure 28. G8P2 asked for a donut, her teammate G8P3 pointed his hand to the donut's position on the board.

Similarly, players leveraged their physical movements in competitive scenarios. In the following example, the player saved power-ups for later by adjusting the distance between the power-up and himself.

> *G4P5: It's important to save up the power-ups…we did this a couple of times. We look at this like, if they are up two points, and they both have the donut, they keep the guy [the Nerd character] away. You save the 'stealth' to when they try to keep it away, like, in the middle of it [the Donut King's attack phase], they are going to lose two points, because you stole it.*
> *Interviewer: But if you keep it, the other team could potentially get it.*
> *G4P5: Yeah.*
> *Interviewer: Did you try to protect it?*
> *G4P5: They [other players] were all on the other side of the board. I saw a 'stealth' over there. I am just going to move there and wait. If it's like there is*

one in the middle of everybody, there is no point of saving it. If one pop over the corner, just go over there and wait.

This example shows a series of observations and actions that this player took while playing. He used his occupancy of the physical space to save the digital power-up until the moment when its value was maximized. It required the player to keep track of others physical distances, judge the time required to reach a target (not only for himself but also for other players), and decide the right timing to use the power-up. The player was able to decide whether a power-up was "savable" based on its position in relation to other players.

Players discussed that one of the biggest challenges of the game control was the integrated camera control and hook control. When a player gets closer to the map, the field of view is reduced proportionally. But during the game, players needed to zoom in-and-out for different tasks—for example, to get a donut, a player needs to lower their camera. When a player zooms in, they see less of the whole game board on their screens. The following quote during the game break discussed this challenge.

G5P2: I think it is a lot harder to watch with your teammate and other people playing since your camera is your controls, and then you start shocking things…
G5P3: Yeah, you really kind of focus on you are doing.
G5P1: That's why communication is important.
G5P2: It is.

This example shows that players leveraged their co-location in the physical space and filled the missing information caused by the constantly moving view window (the camera phone). This characteristic of the game control ("*your camera is your controls*") is critical to the specific type of social game experience during *NerdHerder*, as discussed in further detail in the next section.

In summary, players understood and leveraged the overlapped physics and coordinate systems in both competitive and cooperative play. But it was challenging for players to keep track of all events through the small screen when their game control as the same as the view control, increasing the need to communicate.

Constructing Shared Awareness through Hybrid Co-location

In the CSCW literature, shared awareness means an understanding of others' activities, which provides a context for one's own activity. For multiplayer games, shared awareness provides the foundation for further interaction and communication. We designed *NerdHerder* to support players combining their physical and digital co-location with each other to construct shared awareness. The "Stealth" power-up was designed to temporally take away the digital representations of a player and encourage others to use their physical actions and positions to infer the digital game state.

In the user study, we found that players constructed a shared awareness of the game through verbal communication, observation of in-game activities, and physical movements. One of the most frequent behaviors was calling out the game state based on players' individual observations, including: reporting the hook state (whether it had donut or needed one, when the donut on the hook was just stolen), calling out danger (that a Nerd was about to be stepped on), reporting scores (theirs or the other team's), and talking about the game characters' movement and state. The importance of communication is shown in the following conversation.

> *(Interview with Group3, P1 & P2 were chefs)*
>
> *G3P1: if you didn't communicate, you lost. That one time I switched partner and I didn't communicate, I lost. Basically calling out how many more donuts you need; you know, calling out…*
> *G3P2: It's like working in the kitchen… we need a number 3 or number 1 or…*
> *G3P1: you know, 5 minutes out on me, 8 minutes on you…*
> *G3P2: Because we are chefs, all around communicating in the kitchen, If not, someone has a hot pan, a hot plate… you have to do that, or somebody gets stabbed.*

The frequency and importance of communication, especially verbal communication, was related to the combined camera and hook control as discussed in the last section. Players constantly talked about what they see on their screens, which are windows to the virtual world. The information from multiple camera views was effectively stitched together to form shared awareness.

However, as this verbal communication occurred in a public space, the other team could overhear it and take counter-actions, as shown in the following example.

G5P2: One of the down side of communicating... like they were doing a good job with communicating, what it did a really good job of was telling me the strategies that I haven't just thought of.
G5P4: Argh, it's funny.
G5P2: So I had everything I was thinking of, ***plus*** *all their inputs as well, which didn't seem to help (because that group did not win that time)*
G5P4: right.
Interviewer: interesting.
G5P2: you can't strategize too much. 'Oh, I am about to get their guy squished.' 'Oh, no, you are not."
(group laughter)
G5P1: what you do is to have the baseball movement what you really need is the… I have all the information
G5P4: Well, I think ideally everybody will get to a point where everybody mostly and then get to the point that you can observe your teammate...and you will be like, they are right there observing the nerds…

This discussion shows the problem of verbal communication in coordinating actions in competitive scenarios. Voices naturally call for attention, and are accessible to everyone. In the future, leveraging the individual displays can potentially address the need for secret communication.

Other than human voice, sound design from the system can be leveraged to increase users' awareness of the environment, events, and other users (Gaver, 1989; Mynatt et al., 1997). Several players mentioned the importance of steam engine sound that the Donut King made before his attack.

G2P1: The steam engine is the only sound I paid attention to…
G2P3: …and the squish sound (laughter)
G2P1: Yeah, but it's an after effect. You are like, yeah, right, I can't do anything about it.

The above quote shows that it was the possibility to act upon upcoming events that encouraged players to pay more attention to it. There is silence and little events happening immediately after the engine sound, leaving a few seconds for people to prepare together. Players oftentimes had following actions after this sound, such as calling out danger, coordinating actions with the team, and leading the other team's Nerd to the Donut King.

One pitfall of design is to give as many sound feedbacks as possible. But this needs to be carefully considered in a shared space that the sound from one device can be heard by everyone else. For *NerdHerder* it was especially challenging because there were four devices involved; it was hard to associate sound with its source. This shows the tension between group engagement and individual engagement (Gaver, 1991). An interesting future direction to explore is to combine private with public sound space to enhance the shared awareness for common events while avoiding distraction or conveying secretive information.

Other than sound-based awareness, observing game events on the screen played a critical role in constructing shared awareness. This is reflected in the frequent comments on others' in-game actions. In the following example, a player's action was recognized by his teammate and received positive feedback through the comments.

(G1P2 just got a shake power-up and applied it on the other team)
G1P1: Is that ***you*** *messing with people over there?*
G1P2: Yes (chuckles)
G1P1: Nice.

A third source for constructing shared awareness was through physical movements and positions. Players observe others' physical movement by peripheral vision, and sometimes they even mimicked others' movements. Mimicking one another's physical movement is a sign of synchronization between participants (Perper, 1985). Figure 29 shows a sequence of video clips, in which players (P1 and P3) mimicked their friend (P2)'s body posture to experiment with the different perspectives to view the game world. Here is the transcription:

(In G7, P1, P2, and P3 were high-school friends. PG7P2 was tinkering with the perspective. Five seconds later, his friend P1 noticed that.)
G7P1: how so you get lower?
G7P2: It's so cool you go up this personal if you are a nerd.
G7P4: (laughter) are you kidding me?

G7P3: (chuckle) of course in person…
G7P1: (lowered himself) oh my god! Getting really close is so cool.
G7P3 lowered his camera and perspective too.

Figure 29. G7's players mimicked one of the players' physical positions sequentially

Physical movements are not only game inputs that change camera view and hook position, but also an indicator of the players' state and action in the game. Players tried to observe others' physical movements to understand their in-game state. But the dangling fishing hook made it hard to make a precise prediction. This was revealed around the use of the "Stealth" power-up, which was designed to motivate players to pay attention to others' physical position and movement when the digital presence was not rendered. The following example shows how players used their physical movements to avoid having their donut stolen and observed others' movements in the game, and the difficulties they encountered.

> *G1P2(R): I feel like the coordination that I did, was power-up based. It's like, 'OK, who just got the Ninjia (Stealth power-up)?' If it was my teammate, don't have to worry. If it's the other teammate, oh boy, watch out! I save my donut up here (gesturing that he lifted the camera phone up high)*
> *(Group laughter)*
> *G1P1(R): there is not much you can do…*
> *G1P2(R): Well, I started to play, pull my donuts up here…*
> *G1P1(R): oh…(realized that P2 pulled up his phone to avoid being stolen)*
> *G1P2(R): …while wait for him (the Donut King) to have his mouth open (so that one could score),*
> *G1P4(B): I did the same thing.*
> *G1P3(B): I didn't think about that.*
> *Interviewer: How did you know who had the Stealth power-up?*
> *G1P4(B): It didn't matter, to me, as long as this guy's mouth isn't open, you don't want to be anywhere near the ground.*
> *Interview: It's interesting. The hook was invisible on the screen after they got the power-up. How do you know where they are?*
> *G1P1(R): Well, you don't.*
> *G1P3(B): You just assume they are coming after you.*
> *(Group laughter)*
> *G1P4(B): Paranoia works as a strategy.*
> *G1P2(R): Yeah, How long since the Ninjia power-up disappeared? 3,2, crap…*
> *(Group laughter)*
> *G1P1(R): Yeah, the Ninjia thing is probably the best part, that asymmetrical information. But one thing you can't really, you don't have to perform right on the screen, it's really invisible.*
> *G1P2(R): Yeah.*
> *G1P1(R): If you look at them, you will be like, oh, they are looking over here. It's not really going to help.*
> *Interview: Oh, you mean the hook is not exactly the same position as the person?*
> *G1P1(R): So you can get a feel by looking at the person and see where they point their phone, but it's not accurate.*
> *G1P2(R): By the time you look at the person back to the phone, your donut could be gone.*

In this example, to dodge the player who had the power-up, P2 paid close attention to the timing of a "Stealth" power-up (which makes a sound on every device when triggered). Both P2 and P4 used the same strategy of lifting up their donuts to make it harder to reach. But all players recalled the difficulty of figuring out who held the "stealth" power-up for two reasons. First, it was hard to keep track of who just got the Stealth power-up. Although a sound was played as a reminder, a player might be focused on their own tasks at that moment and did not see which player got it. Second, players did try to leverage their observation of the other person (instead of their in-game representation as a hook) to infer where they are — "*you can get a feel by looking at the person and see where they point their phones*", but it could not be precisely predicted because the hook dangled from the camera phone. The mapping between the digital hook and players' camera phone (where the digital fishing rod extends from) is a rough approximation. Therefore it is difficult to map the physical presence of the player to the digital presence of their hook. We could improve the design by having visual/acoustic reminders about who holds the power-up and introduce other mechanics that supports a more precise understanding of the mapping between the digital and physical presences.

In summary, players leveraged verbal communication, observation of on-screen events, and physical movements to construct the shared awareness in the hybrid physical-digital space. But due to the imprecise mapping between the digital and physical presence, it was challenging for players to infer where the other players' hook was based on their physical movements.

<u>Joining Players' Attention with the Common Objects</u>

In the above two sections, the natural mapping between the physical and digital and the construction of shared awareness through hybrid co-location of players formed the foundations for players to interact and communicate with each other. The rest of the findings are built on top of this basis. The following three design elements target supporting mutual focus of attention.

One way to support mutual focus of attention is through shared objects that multiple players can change the state of. In *NerdHerder*, we implemented common objects, such as the shared goal of the Donut King and the shared characters of Nerds to motivate players to pay attention to the same object and activity.

In the user study, players commented on and joked about the behaviors of the Donut King during the games. The behavior of the Donut King also created a shared enemy between teams and consequently generated shared emotions around it, which is discussed in the next section. Players learned about the movements and physics of the Donut King collaboratively through group discussions about the same object.

> *(G1 was divided into two teams: P1&P2 in team red, P3&P4 in team blue. All participants are classmates)*
> *G1P2(R): So does the Donut King just like homing on people?*
> *G1P1(R): Yeah, it really feels like he is after blood.*
> *G1P2(R): Yeah, you can try as hard as you want to keep him away. But at some point, it's like, 'Ah-ha, I am seeking you'.*
> *G1P1(R): Yes, like right now, I am going to bring the blue guy (the other team's Nerd) over to the Donut King.*
> *G1P2 laughed.*
> *…(Donut King started charging at the Nerds)*
> *G1P4(B): Good. I am going to get the red guy to the Donut King. Come on, red, come on!*

In this example, players discussed the AI (artificial intelligence) of the Donut King based on their observations. Players from the blue team also learned from other team's conversation and followed the same strategy.

Players observed others' actions around the same goal of the Donut King, commented on them, and developed strategies based on this feature. Three groups developed an unexpected strategy, repurposing the power-ups as gatekeepers to the goal (the Donut King's mouth). Instead of using the power-up against other players directly, some players hovered the Shake or Stealth power-up on top of the Donut King's mouth.

> *G7P1: 'Stealth' is my favorite one. Because you guys will be all waiting, like, try to feed him, right when he was about to open up again. Then I will just steal it (the donut)(Laughter).*

This strategy shows that some players were able to turn the observation of the shared target of the Donut King to their advantage. Moreover, they combined it with the features of the power-ups, e.g. power-ups work within certain range and the Stealth power-up makes the hook invisible. This emergent strategy turned out to be effective.

Similarly, the shared character of the Nerds gathered players' interest in multiple occasions. Between teammates, sometimes players divided the tasks to make sure someone was protecting the Nerd, to keep them away from the Donut King, and sometimes they lead the Nerd together. The following example illustrates the latter.

G5P2(R): Jake, strategy number two, we are at zero points, so lure their blue guy into him.
G5P1(B) chuckled
G5P2(R): because we don't lose anything. Get him smashed!
G5P4(R): yeah, bring them down to zero
G5P1(B): no…no…no (raised voice)
G5P2(R): come here blue guy
G5P4(R): come here blue guy, come here blue guy. (Laughter) He is so confused.

Players from different teams competed for the control over the same Nerd character. Since both teams could lead the Nerd by a donut, players can choose to protect their own Nerd or to lead the other team's Nerd into danger. Players commented on the fact that both teams could affect the nerds:

G3P2: Nerds, donut nerds, they are not loyal to nobody. They can be on your team, but they will follow the other team in a heartbeat over a donut. You can't trust them. What you can do, if you are in a scene that once sets you up, you put a donut in front of their head, 'don't you follow the other team'…

Most groups (7 out of the 8) constantly used the strategy of leading the other team's Nerd into the Donut King. The following example shows how players fought head-to-head for the control over one Nerd. The competition often increased emotional intensity and lead to shared laughter or faster pace of communication.

G1P1: Stay back, stay back (talking to the Nerd with raised voice)
G1P3: No, no, no!
G1P1: I will protect you (the Nerd)
G1P3: No, I won't! I won't! (Raised voice and laughter)

In summary, the common objects we designed motivated the interactions between teammates and two teams. The activities on the same object required paying close attention to what others were doing with it, which created joint attention among players.

Dependency between Teammates

To encourage players to pay attention to the other players, we increased players' dependency on each other by enforcing the need of multitasking. After tuning the game, players could not win by focusing on individual tasks only (i.e., feeding the Donut King with a donut). We expected to see that players communicated with their teammate and paid close attention to each other's actions.

In the user study, the most frequent behavior category was players' collaboration with teammates with a variety of interactions and communication, including 1) suggesting and coordinating actions, 2) asking for resources or help, and 3) emotional exchange and sharing.

The first interaction (suggesting and coordinating actions) was the most common form of collaboration. It usually started to happen after players observed that their Nerds were squashed by the Donut King a few times, and realized that they needed to collaborate to perform better. The conversation often included players reporting their current states and observations or the next action to the other player, and suggestions for what the teammate needed to do. For example,

> *G8P1: No no no no, get him away, get him away. (The Donut King was after the Nerd)*
> *G8P3: We are still doing good. They [The other team's nerd] are dying.*
> *G8P1: I will try to grab donuts, you lead them away.*
> *G8P2: Yeah. We are doing good, we are doing good.*

While some players followed their teammate suggestions and tried to fulfill their role, it did not always happen due to the different priority that an individual player might have. In the following example, P3 was unable to follow P5's suggestion because he was busy finding a donut, and a player could not lead the Nerd around without a donut.

G4P5: Go Sam! I keep the Nerd away from the Donut King; you focus on scoring.
G4P3: I'm just trying to get any donut, period.

Another form of teammate interaction was seeking and helping other players. For example, when a players needed to lead the Nerd away from being stepped on by the Donut King, but did not have a donut, they may ask teammate where they could find one. Players also helped others to learn the game by sharing the "tricks" they figured out. In the following example, G2P3 observed that his teammate G2P4 did not seem to use the range of influence of the hook properly and pointed it out.

G2P4: (laughter) Did he just go into the guy?
G2P3: Don't, don't…Andy, Andy (trying to get P4's attention)
G2P4: Yeah?
G2P3: Move high above, because it lowers the amount of influence an individual donut has.
G2P4: OK
G2P1: Yeah, higher-up donuts are less interesting [to Nerds] than lower donuts.

We did not design a direct helping mechanism between players or complementary capabilities that are attached to player avatars, and consequently, the frequency of helping behavior was lower. Two participants suggested adding "ally" power-ups that a player could use on their teammate to increase power or generate new abilities because of the collaboration.

The dependency between teammates also led to emotional exchanges and sharing between players, including encouraging, comforting, cheering with, apologizing to teammates. Players had high-fives; fist bumps, and laughed together when winning.

Figure 30. Winning moments: (above) G1-Fist bump; (below) G5-High-five.

The cooperative efforts did not always have positive results; some players blamed their teammates, which might cause annoyance or other negative feelings. For example,

> *(G7 was divided into two teams: P1 & P2 in the red team and P3 &P4 in the blue team. P1 and P2 divided the task earlier—P2 was in charge of protecting the nerd, P1 was trying to score. P1 and P2 are high-school friends)*
> *G7P1: Jim, Jim! (raised voice)*
> *G7P2: What? We are red, dude.*
> *(group laughter)*
> *G7P1: Yeah yeah yeah…sorry, I just saw a guy get crashed; I thought it was you.*
> *G7P2: Thanks for having faith in me! (said sarcastically)*

Emotions were both outcomes and input of the interaction. Through the process of players talking with and helping each other, the emotions in the game experience are synchronized and intensified.

In the end, it is worth noting that the attention spent on the teammate is not constant. Players tended to switch their attention between their own actions, teammate's actions, and the other team, depending on their focus at that moment.

> *G2P2: it really depends. Every once in a while I was super aware what she was doing. And then I focus on keeping our little guy away that I completely lose*

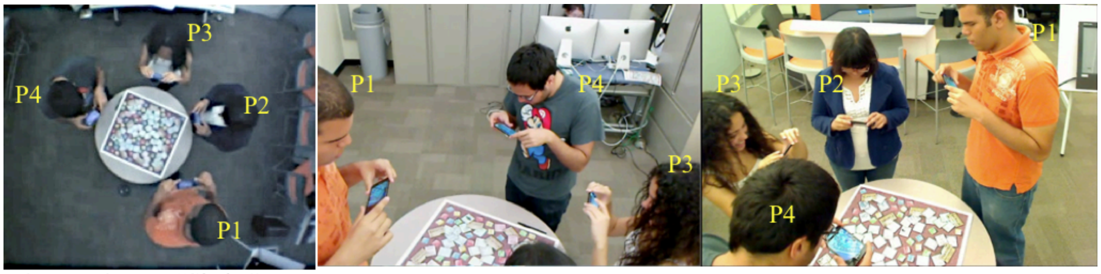
track of everybody else. So it really went back and forth depending on what I was doing.

In summary, teammates had frequent communication and emotional exchanges, much of which was triggered by the need to collaborate. They coordinated actions, helped each other, and shared laughter and frustration.

Conflict with the Opponent Team

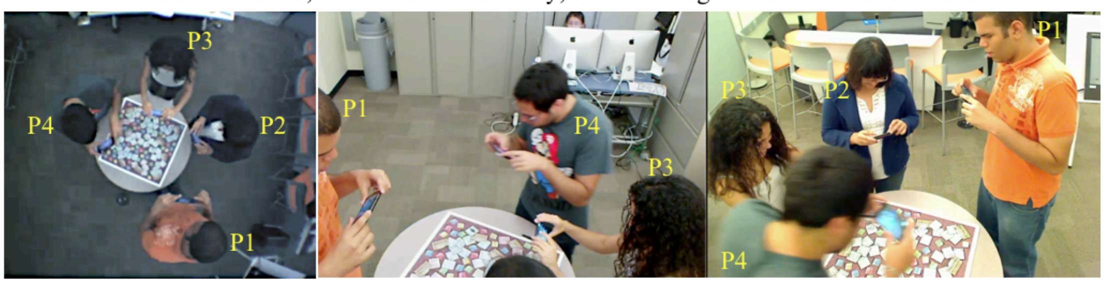
To motivate players to pay attention to the other team, we created explicit conflicts between the two teams. We designed distance-based power-ups, meaning that players need to directly target the other team's players to use it, increasing their motivation to pay attention to the other players' physical and digital presence. Players can also go head-to-head when they fight for the donuts and the control of the nerds (as discussed in 9.1.1.3).

In the interview, several participants commented that they were most aware of what the other team was doing when they fought for or used power-ups. In the video analysis, I found that the use of power-ups increased the direct conflict between players, which led to physical movements, emotional expressions, and trash talking. In the following example, the log data of power-ups matched perfectly with moments of players' physical movements and emotional expressions.

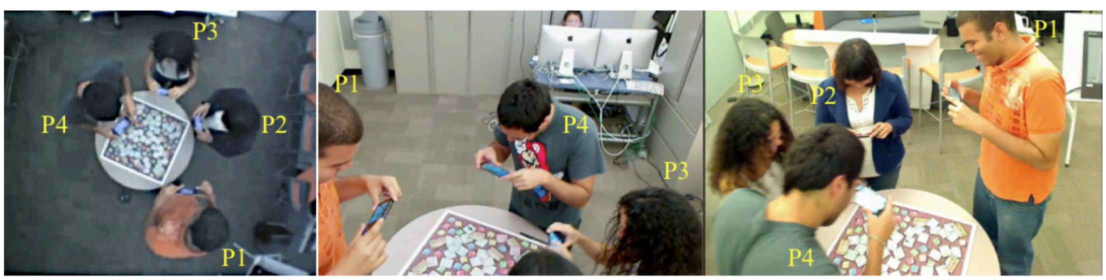


6:57 - P4 got a “Shake” power-up

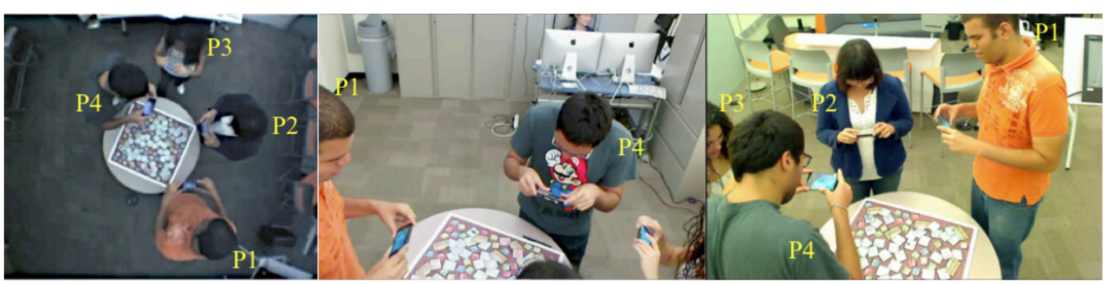
7:00 - P4 moved towards P3, P3 moved further away; 7:02 - the log shows that P4 shook P3’s hook



7:07 - P3 and P4 both moved towards the power-up of “Stealth”, P3 started giggling; 7:09 - the log shows that P3, who was closer to the power-up, got it



7:10 - P3 and P4 laughed, and P1 started smiling; the log shows that P4 stole a donut from P1



7:15 - P3 and P4 both moved towards the “Shake” power-up; they laughed louder together; 7:16 - the log shows that P3 got the power-up this time.

Figure 31. G6 players’ movements and reactions to each other, corresponding to game events; the physical movements indicated defense and offense.

As shown in the Figure 31, players physically moved themselves to get the power-up, use it, and dodge it. Players were aware of the competitor's moves and responded to them. In the video, the players' moves were synchronized in such a way that they looked like they were dancing. A sequence of the competitive actions around power-ups elevated the intensity, and players' mood was synchronized and reinforced with the competitor.

Trash talking that happened with such competitive scenarios also added to the intensity of the experience. In the following example, G7P1 and G7P2, who were real-life friends but in different teams, had the following conversation.

G7P1: (Laughter) You like that, Jim? You are out of the map and I stole it (the donut that was on P2's hook).
G7P2: Argh, it's OK…in the game… and in real life…
(Group laughter)
G7P3: No, in NerdHerder
G7P4: You just said that on camera. It's gonna… (can't discern)
(Group laughter)
(A few seconds later, P1 stole P2's donut again…)
G7P1: Hey, Jim, thank you, haha…
G7P2: Oh Josh, no, stop that. You've no right! (laughter) Who do you think you are? Sorry, I am going to lead your person right into the path of the death.
G7P1 laughed.

In this example, P1 showed off after he stole a donut. P2 joked about it, followed by P3 and P4's comments and shared group laughter. When competition happened again, the game become more serious and P2 was motivated to take "revenge" on P1. This showed that the conflict between players could trigger other conversations and emotions, which contributes to players' engagement and enjoyment of the game experience.

When the in-game competition overlapped with the out-of-game relationship, the social dynamics between players showed that they switched between the frame of gaming and real life. For example, G5P1 cursed as a response to her donut being stolen. But almost immediately, she said something nice to her friend, who just stole the donut, to make it up.

G5P1: Urgh…you bastards! (frustrated after her donut got stolen)
(group laughter)
G5P1: It's OK, my friend.

In summary, the conflicts between teams brought more heat to the gameplay. Players physically moved themselves to compete for resources and dodge being attacked the other team's power-ups. The shared mood between players was reinforced by trash talking, jokes, and expressions of emotions. The in-game competition may also overlap with players' real life relationship, which generated dynamics that switch between the frames of real and game worlds.

Shared Enemy

In the IR model, the mutual focus of attention and shared mood reinforces each other. While the previous three design elements focus on supporting players' joint attention, whether on common objects or on each other, they also encouraged players to exchange and share their emotion, especially between teammates. To bring out shared emotion between the competing teams, we designed the shared enemy of the Donut King. In the game, the Donut King charges at both the Nerd characters every time he eats four donuts. We also put in a few second of delay for players to prepare for the attack phase and increase the intensity of the emotion by "dramatic anticipation" (Booth, 2009). The burst of emotions frequently happened during the Donut King's attack phase.

In the user study, the competing two teams shared similar kind of frustration when both of their nerds got attacked. Especially when the two Nerds are clustered, they got run over by the Donut King together. Players raised their voice, cursed together, and laughed together.

G5P4: Are you serious? Are you serious?
G5P1 (loud laughter)
G5P2: I think there should be a third team, with one person, that's the donut king.
G5P4: Yeah…(laughter)
G5P1: (Smile) I agree. That would be awesome.

Some players observed this problem of clustered Nerds and decided to keep the two Nerds separate. For example, at the beginning of a game, G5P1 told his teammate at the beginning of the second game, "*I am going to be busy, try to separate these guys*."

But one team chose a different path—they decide to collaborate with each other disregarding the preset game rules. Before they decided on between-team collaboration, players from one team commented on the Nerds being attacked at the same time.

(G2 was divided into two teams: P1&P2 in team red, P3&P4 in team blue. P1 and P2 are friends; P3 and P4 are roommates)
(Both the Nerds just got squashed)
G2P2(R): Oh no, just completely…(Raised voice)
G2P3(B) chuckled
G2P1(R): Well, now they are both together. What is good for one will be good for the other.
G2P2(R): Good for the goose, good for the gander.
G2P1(R): Yes (chuckled)…which directly counteracts the whole point of trashing element of destruction, but…never mind that.

Later in the game, when once again both Nerds got squished, the two teams decided to work together.

(both the Nerds get squashed)
G2P2(R): what? I was right there....(frustrated tone)
G2P1(R): (chuckle) "squish"…"squish" (the sound played when the nerds were stepped on by the Donut King)
(Group laughter)
G2P4(B): Is he just going back over in the same track over and over again?
G2P1(R): Yes. That … was awful.
G2P2(R): That is.
G2P3(B): Do we want to try to just work together to get the objective completed?
G2P1(R): I think so.
(Both the Nerds get squashed again)
G2P(R), P2(R), P4(B): Urgh, OK… (at the same time)
G2P4(B): I was trying to lure him away.
G2P2(R): I don't think you can…oh…I see what you mean, never mind.
G2P1(R): It's not…working.
G2P3(B): OK, let's take care of the Nerds.

The collaboration was suggested by P3 when both the Nerds get squashed together. One of the other team's members (P1) verbally agreed. But the group did not have a plan yet for collaboration, and their Nerds continued to be squashed by the Donut

King. In the communications after the above quotes, this group quickly figured out that they had to divide the tasks, instead of everyone trying to lead the Nerds at the same time. They agreed upon which team they wanted to support to win, which players should be in charge of scoring, and which players should focus on keeping the Nerds away from the Donut King. After they communicated and adjusted the strategy accordingly, they won the game as a group together. They burst into laughter and had high-fives between the two teams (See Figure 32).

Figure 32. The high-fives between two teams

In this example, when players faced the shared enemy of the powerful Donut King, they decided that it was too difficult for them to win the game with the existing structure. They changed the rules to make the game more fun to play (DeKoven, 1978). This emergent change from competitive to cooperative play can be compared with the findings from the Robbers Cave study on conflicts and resolutions. In the study, the two boy scout groups, who were at conflict because of limited resources, eventually formed positive intergroup relations in the presence of a superordinate goal, which promotes united, cooperative action. While researchers in the Robbers Cave study imposed the goals for the groups and changed participants' intergroup friendliness, in *NerdHerder* study, players changed the goal themselves to accommodate the need of enjoying the time together. The shared frustration caused by the Donut King reinforced the solidarity of the group (it was 'us' against the Donut King), and motivated them to make changes for group enjoyment even in a study setting.

In summary, the shared enemy of the Donut King created a shared mood among players. It helped to get players to synchronize their emotions despite the team division. In one group, it even motivated players to change game rules from competition to cooperation.

<u>Humorous Content</u>

The character design, animation, sound design, and the premise of *NerdHerder* are light-hearted and funny, easy for players to make relatable jokes and share them with others.

Throughout the user study, players made jokes about game content, relating the game to their real life experience. For example, during the chat between games, the players discussed "feeding" as actions in the game and in real life.

> *(G5 just finished a game. In the next game, they decided to change partners-P1 &P3 would be on the same team, P2&P4 on the other team)*
> *G5P1: I am really good at feeding (the Nerd).*
> *G5P4: I am good at that too. (Smile)*
> *G5P2: So my goal is basically to knock down all of your work. Like, I am crashing…*
> *G5P4: Well, you can either crash them or prevent your guys getting crashed.*
> *G5P2 J: we should have brought XXX (a friend's name). He is really good at feeding.*
> *G5P1: See, I am really good at feeding people in the real world. (Laughter)*

One of the other most common activities was mimicking the sound of the game characters. All the groups had moments when someone mimicked the Nerd attracted by the donut, or the "yum yum" sound of the Donut King eating a donut.

Players also discussed out-of-game content inspired by the game content. For example:

> *(G1 was divided into two teams: P1&P2 in team red, P3&P4 in team blue. All participants were classmates)*
> *(The Nerd character that belongs to the red team is a nerdette; The Nerdette just got squashed)*
> *G1P1 (R): (singing) "Hey girl, this is crazy."*
> *(G1P2 (R) chuckled)*

G1P4 (B): There is a Sesame Street "Call Me Maybe" now.
G1P1 (R): No way.
G1P2(R): Is it?
G1P4(B): It's Cookie Monster.
G1P1(R): Oh, fantastic! Singing about cookies?
G1P4(B): Yeah, it's called "Share It Maybe."
(G1P2(R) chuckled)
G1P1(R): Awhh…
G1P4(B): It was brilliant; I just saw it today.

In the above example, players discussed a song inspired by one player's singing, which was a reaction to the character being squashed. The singing and the donut-eating Donut King made the connection to a piece of pop-culture outside of the game itself.

In summary, the humorous game content became a trigger for players to have further expressions and discussions that were interesting.

Other: Spectator Experience

Although we did not intentionally design for supporting spectator experience, one of the groups (G4) happened to have one extra participant and took turns being a spectator, which gave us a glimpse into the spectator experience of the HAR game.

One of the challenges of mobile games is the limit of the small display and input device, so that the actions and feedback are "secretive", discouraging spectators from keeping track of the game state. In the G4, spectators watched over-the-shoulder what players were doing, listened to the conversations, and commented on the game state. However, the digital information was rendered only on the small screen. Although the actions (movement-based control and communication) were accessible to a spectator, the feedback (the reaction of the game characters and game state changes) were only rendered on the screen digitally. This leads to the unique experience of seeing players' actions but not the digital feedback.

Interviewer: How to feel like to be the person who was watching the game?
G4P5: it's funny to watch. All of them just stand around, like, tons of commentary, 'Oh God', 'No I got this'. There is nothing happening in real life
G4P3: Yeah, unless you…

G4P4: You could see what's going on the screen behind them over the shoulder, but you just see four people being loud, moving around and there is the board.
Interviewer: what do you mean by 'nothing happening in real life'?
G4P5: If someone walks by with the door open, they see the four people around the board with nothing going on
G4P4: Waving around
G4P5: What's going on? …There is nothing like you can see unless you look at the screen. If someone sees this, they'll just walk away, because it is weird.
G4P1: Unless they were used to this sort of thing.
G4P5: It's not like someone playing the Wii, you can see what they were doing, they are moving.
Interviewer: The screen…
G4P3: But watching the screen could be sometimes a little challenging because they are constantly moving with the phone.
G4P4: I got in their way a couple of times

In Group 4, the spectator smiled when watching the game over the shoulder, commenting on the status and laughed together when dramatic events happened. But they also get distracted after several minutes of watching the game. As shown in the above quotes during the interview, watching over the shoulder was not ideal for a spectator, they got in the way of other players, especially in a game like *NerdHerder* where players moved a lot. The meanings of the physical actions needed to be paired with the digital information to be interesting to a spectator.

In summary, the physical actions displayed part of the game information. But for a spectator, such information needs to be paired with digital feedback to understand the game state.

Summary

The findings depict how players interact with each other during the gameplay of *NerdHerder*. It answers the first sub question 1, "what kind of interpersonal behaviors emerge from playing *NerdHerder*", by presenting the diversity of intra- and inter- team interaction and communication. These behaviors are expressed through verbal communication, non-verbal utterance, bursts of emotions, and body movements and gestures. The findings also answer the second sub question 2, "how does the theory-based design guideline support these social behaviors" by looking into the game state changes and interactive capabilities that sequentially lead to or fundamentally support these behaviors. The findings are organized after each of the design guideline and its associated behaviors. The third research question, "What is the role of reality-based interfaces (i.e., Handheld Augmented Reality) in supporting these social play behaviors in the shared hybrid space", is partially answered through 9.1.1.1 and 2, and will be further discussed in the next section.

Discussion

The user study depicted how players interact with each other and with the game. It also revealed the challenges and problems that need to be addressed to improve the game experience. Reflecting on the findings from the user study and the design choices and iterations, I want to focus on discussing the following three topics, 1) joining attention together; 2) bodily co-presence in the shared hybrid space; and 3) the role of camera control in shared awareness.

Joint Attention

In games with reality-based interfaces, players' attention is distributed across the boundaries of physical and digital spaces, the game and real worlds. For example, during the gameplay of *NerdHerder*, players' attention splits among the phone screen where game events and states are shown, the physical space where players move, and the sound space of verbal communication and non-verbal utterance. In multiplayer games, the distribution of attention is a challenge for designers to join players' attention together onto the same activity and object, at certain space and time.

In an earlier version of *NerdHerder*, we already integrated competitive and collaborative motivations in the game, including the power-ups and multitasking requirements. However, players still tended to focus on their individual tasks instead of interacting with each other. The playtesting sessions were quiet except for occasional comments or expressions of emotions. Through playtesting, we learned that: 1) players had little attention to spare with the fast pace of game events, and more importantly, 2) there was a high chance that a player could win the game by just focusing on the individual tasks. These lessons were somewhat surprising to us designers because we underestimated the effort for players to keep track of the others in comparison to their own activities. Therefore, the game needed to provide even stronger motivations for player to pay attention to other players' activities to encourage them to interact with each other. To achieve this goal, we tuned the Donut King to be smarter and charge at the Nerds periodically to increase the need for collaboration. We also made the power-ups distance-based, so that players need to track others so that they can dodge or chase others effectively. We reduced the speed that the donuts and power-ups get generated on the game board to lower the speed of the game and to allow players to have more attention to spare. All these changes were dedicated to support players joining their attention to common activities and targets. As reported in 9.1.1.3-5, tuning the game mechanics had a positive effect in creating more opportunities and cognitive bandwidth for players to pay attention to each other and shared objects. Players coordinated with teammates and discussed strategies; they also kept an eye on and responded to the other teams' physical movements and digital presence.

Joining players' attention not only helps improve their performance, but also enhances the emotional experience. Players share and synchronize emotions based on the joint activities. As shown in 9.1.1.4, teammates encouraged, comforted, cheered with, and apologized to each other. Between the two teams, they raised the heat of the game by head-to-head competition and trash talking (as shown in 9.1.1.5). The increase in the intensity and amount of the emotions is based on players' awareness of each other's state and emotion, which is not possible without joint attention on common activities.

The shared emotion is not merely an outcome of shared game experience; it can also change how people play the game. This is the most apparent in the analysis in 9.1.1.6, where the common enemy triggered players' shared emotion (e.g., tension and frustration in *NerdHerder*). Players cursed and laughed together, commented on the experience, and learned the game collaboratively, around the shared experience of being attacked by the Donut King. In one group, players even came to the common agreement to change the rules to play against the Donut King together. The emotion and joint attention formed a reinforcing loop, as predicted in the IR theory model.

The contrast between the lack of social interaction in earlier versions of *NerdHerder* and the richness of social play behaviors in the current version shows that motivating players to join attention is fundamental to social play. When a player starts to pay attention to other players and common objects, their awareness of each other increased, more interaction and communication is triggered, and emotions get synchronized and reinforced.

Bodily Co-presence in the Shared Hybrid Space

In *NerdHerder*, players leveraged their bodily skills for various purposes—they changed inter-personal distance with other players during the competition (9.1.1.5); they occupied physical-digital locations by positioning themselves (9.1.1.1); they pointed at spots containing resources on the game board using hand gestures (9.1.1.1); they controlled the camera view by zooming the camera phone in and out. This variety shows that body actions are not only used as game inputs in a reality-based computing environment, but also as external displays of in-game game states for other players in the hybrid social space. At the same time, players can observe the others' body movement and guess their intentions. For example, players understood that when someone got a "shake" power-up and started to move towards you, they had the intention of shaking your hook. Players responded to this with dodging movements.

The bodily co-presence discussed in the IR theory is the foundation for social interaction because it supports people keeping track of one another's actions and emotions. The meanings of these actions are mostly based on culture, norms, and the context that the interaction is situated in. In contrast, games create a different frame where players' body actions are mapped to different game-defined meanings. In a good game design, the mapping needs to be intuitive and easy-to-learn for both the player and the viewers. For example, in the *NerdHerder* study, players complained about the imprecise mapping between the digital hook and physical camera phone positions because of the dangling effect. It was difficult for a viewer to infer where the other player's hook is when it disappears from the screen, and can only be traced by others' body position and movement. To improve the game so that players can better leverage their bodily co-presence, we need to introduce more precise mapping mechanisms between the players' movement and their avatar (the hook)'s movement.

The Role of Camera Control in Shared Awareness

Camera control in digital games is highly interactive and is critical to the rest of the game experience. "*The camera is the window through which the player interacts with the simulated world.*" (Giors, 2004) The existing types of camera control in digital games include: first person, third person, and action replay (Christie et al., 2008). Researchers have started to investigate the role of cameras in multiplayer digital games (Voida et al., 2010). Seif et al. identified camera setting as a design pattern that are strongly related to interactive behaviors such as "waiting for each other" and "got in each other's way". Voida et al. discussed the role of split screen and multiple views in constructing shared awareness.

NerdHerder ties players' motion controls to the camera view and the tool that affects the digital world (the fishing rod and hook). In other words, the camera is the controller. It combines the first person view with a top-down perspective view (which is more common in third person view games). With this camera control, players understood the alignment of coordinate systems in the digital and physical worlds, and expected the physics in the digital world would work identically to the physical world. This section focuses on discussing the role of camera control in constructing shared awareness among players.

In the user study, players came to the realization that their physical motions (e.g. panning and zooming the camera phone) changed the field of view while trying to act upon some in-game objects. With the small screen that a player views the digital world through, it is hard to keep a view of the whole game board most of the time. Players commented that to compensate for the limit of the small screen and constantly moving camera they need to rely more on the communication to keep track of the game events (9.1.1.1). Players were constantly talking our loud about their actions (e.g., scoring, having a donut stolen, protecting the Nerd, etc.) and calling out what they observe (e.g., the Donut King chasing the Nerd, other team scoring, etc.) (as shown in 9.1.1.2). Players also pointed out resources for their teammate when it is on the part of the board that they did not see (9.1.1.1 and 9.1.1.4).

In first person shooter games, this kind of limited and constantly moving camera control is common and players communicate their game state with each other even when they have split screens accessible to multiple co-located players. However, players need to be familiar with the digital landscape to be able to stich different perspectives together. In some other games, the camera setting forced players' avatar to be spatially near each other in the digital space to proceed (e.g. Lego wars). These games rely on players' shared mental model of the digital space to construct shared awareness through multiple camera views. Comparatively, in *NerdHerder*, players are aware of others' perspectives because they see the position of other players' camera phones in real world, making it easier to understand the others' perspectives and integrating them.

CHAPTER 10

REFLECTION

This thesis takes a player-centric approach and explores co-located social play and its underlying elements and process by theoretical and empirical methods. While focusing on the shared hybrid space enabled by handheld augmented reality interfaces, I research how social play is affected by game interfaces, design choices, and players' bodily and social skills. Drawing from the design lessons and user studies of three HAR games, I reflect on the commonality and differences among these projects. The following conceptual constructs emerge to play an important role in supporting the cognitive, behavioral, and emotional aspects of social play experience. They are interpreted under the context of co-located hybrid games and with the goal of enabling game design for an enjoyable and social experience.

1. **Co-presence**: the sense of co-presence ("being there together") can be supported through bodily and mediated communication channels. Moreover, game design needs to motivate players to leverage their physical and digital proximity to interact, generating co-presence as an outcome.
2. **Mapping**: With reality-based interface, players' interactions can be mapped naturally to the game state in different ways. Intuitive mapping is the foundation that enables players to observe and discern one another's state in the game.
3. **Intention**: The ability to identify others' intention from their actions enables complicated social interaction and encourages players to pay attention to one another.
4. **Attention**: Attention is a scarce resource that decides where people focus their "processing power". Joint attention is critical for social play.

5. **Emotion contagion**: People are susceptible to others' emotions and mimic them. Emotional stimuli can change how players behave and generate the seed for synchronizing moods and shared emotions among players.

These concepts are extracted because of their important roles in supporting player experience in a shared hybrid space as found in the user studies on HAR games. For each of them, I first briefly introduce their meaning based on the literature, and then discuss how the empirical data and design choices in this thesis work are interpreted through the lenses of these concepts. All of these concepts except intention have been discussed extensively in Interaction Ritual theory and Frame Analysis.

Co-presence

The concept of "co-presence" or "social presence" originated in sociology, to describe the subjective experience of being together in face-to-face, body-to-body interaction (Collins, 2004; Goffman, 1973; Mead, 1925). With the development of computer-mediated communication and shared virtual environments, remote users' co-presence can be supported through the mediation of technologies, such as video/audio chat and online avatars and environments (Durlach & Slater, 2000; Schroeder, 2002; Sheridan, 1996; Steuer, 1992). Co-presence is measured through people's behavioral engagement (i.e., interdependency and attention allocation) and psychological involvement with others (i.e., empathy and social relatedness) (Biocca et al., 2001; De Kort & Ijsselsteijn, 2007). In digital games, the spatial setting between players affects the means and communication channels that support co-presence, e.g., verbal, gestural, expressional communication channels for physically co-located players; voice chat and text for remote players, avatars' body actions and expressions in a shared online space (De Kort & Ijsselsteijn, 2008).

In co-located Augmented Reality games, players have both physical and digital proximity. Players are next to each other while their in-game representations are in the same digital space registered with the physical objects. The *BragFish* user study finds that the registration between physical and digital worlds increases players' co-presence. According to the survey, players' social co-presence is the significantly higher when they share the same game board. Compared to other conditions, the shared game board enables players to use peripheral awareness, which supports one player in tracking another player's physical movements, body position and orientation. Furthermore, players can map that information to the other player's in-game actions, which is a strategy players have adopted due to the tight registration between physical and digital worlds. Hence, it is intuitive to map between digital and physical actions, making the observation of physical movements (compared to just using physical movements as game inputs) an integral part of social play.

As game researchers have found, the physical proximity between players or the digital proximity between players' in-game representations does not always lead to higher sense of co-presence (De Kort & Ijsselsteijn, 2008; Ducheneaut et al., 2006; Magerkurth et al., 2004; Szentgyorgyi et al., 2008). However, in the Interaction Ritual theory, co-presence is considered to happen automatically when people enter the same physical space because of the innate ability of human beings to be in tune with others (Goffman, 1967). The contrast between sociological theories and empirical findings from studies of certain multiplayer games shows that co-presence as subjective experience requires users' intentionality, while the physical/digital proximity and technology mediation can provide the means and channels to support it. However, just using communication tools does not always increase co-presence, for example, a person using a mobile phone to check Facebook during dinner may distract from the sense of being together among co-located companions (Srivastava, 2005). While much research effort has been devoted to building new technologies that support more channels for communication and interaction, the design lessons from my projects show the importance of designing for the social interaction incentives to increase co-presence.

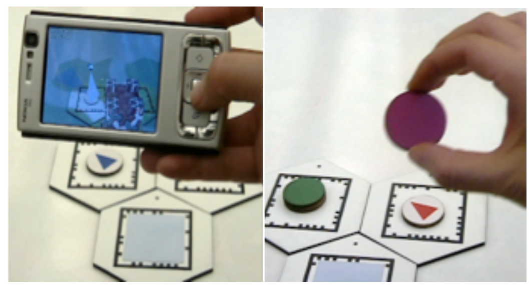
In an earlier version of *NerdHerder*, we tried to encourage players to interact with each other by incorporating competitive incentives (e.g., power-ups for attacking the other team) and collaborative incentives (e.g., the double goals of feeding the Donut King and protecting the Nerds). However, players still tended to focus on their individual actions and did not interact frequently with other players. The playtesting sessions were quiet except for occasional comments or expressions of emotions. To solve this problem, we reduced the game's pace so that players had attention spare to notice what others were doing. Moreover, we made it very hard for a player to win by only focusing on individual tasks. In the later playtesting and user studies, players' interaction frequency and intensity was increased. They constantly talked to each other and used more physical movements for communication. The behavioral and emotional aspects of co-presence among players were rated high according to the survey. This improvement showed how tuning game incentives and pace changed the players' attention distribution from individual activities to joint activities and objects, which started conversations, observation, emotional contagion and players forming strategies based on others' actions. As an outcome of these inter-personal behaviors and emotional synchronization, players' co-presence increased through behavioral engagement and emotional involvement.

Mapping

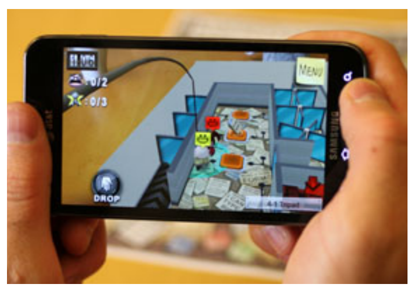
In HCI, mapping is typically used to refer to the relationship between the controls and their movements and the results in the world (Norman, 1988). A natural mapping "*takes advantage of physical analogies and cultural standards, leads to immediate understanding*" (Norman, 1988). In game research, mapping means that the player's time and actions are projected into a game world (Juul, 2004). Note that the mapping concept focuses on "control" in HCI, in comparison to "meaning" in games. In digital games where a player uses computer interfaces to interact with a machine, both aspects of mapping need to be designed for. As I analyze in Chapter 7, a digital game has the frame switch between physical and digital spaces (for control), and between game and real worlds (for meaning).

Handheld devices typically provide a variety of control mechanics, such as touch screens and accelerometers. HAR technology supports a set of interaction mechanisms that are unique, due to its physical presence in the space and the first-person view "through" the device. Through HAR interfaces, users can perform actions via three mechanisms:

(1) BragFish



(2) ARt of Defense



(3) NerdHerder

Figure 33. Mapping mechanisms in three games. (1) *BragFish*: projection from screen center; (2) *ARt of Defense:* object three manipulation; (3) *NerdHerder*: device maneuvering.

1). Projection from screen to space. A common approach is the raycasting mechanic that has been widely co-opted from other 3D games. For example, in *BragFish*, a ray is cast from the device screen to the virtual world, originating from the center of the screen. This is the crosshair players use to aim a fish. This category of actions relies on a player's familiarity with the action of pointing and aiming, which is mapped to the actions of focus and selection in the digital game world.

2). Physical object manipulation. A player can move, rotate, and tilt tracked objects in order to affect the virtual objects in an analogous way. For example, in *AoD*, players move tiles and place tokens to deploy the corresponding digital units.

3). Device manipulation. A player may pan, zoom, and shake the handheld device (e.g., the "earthquake attack" in *InviZimals* (Novarama, 2009) is launched by shaking the device). Movement of the device can affect the game state, either by changing the movement of the characters or changing the environment. For example, in *NerdHerder*, players use the device as the fishing pole and also a window to the digital world. When players need to hook an object, they lower the camera phone towards the game board; when they need to attack the other players' hooks, they move their devices (and typically also their upper body) towards them.

Intuitive mapping from user input to game state supports players in observing one another's actions, and mapping them to their in-game state changes. This allows players to use their bodily and social skills to benefit their gameplay. Moreover, this provides motivations for players to pay attention to one another, both in the game and in the physical space. In *NerdHerder* and *AoD*, the digital objects are directly attached to the physical objects/device that players control by their hands. This direct mapping leads to immediate perception and understanding about game states. During *NerdHerder*, players understood where others were viewing and pointed out the resources or danger that might be invisible on other players' devices. The ability for players to understand others' camera viewpoints supported shared awareness in the game. During *AoD*, players used the reference system and gestures in physical world to refer to digital objects. The direct mapping between physical game pieces and digital game objects formed the common ground for players to communicate about game-events.

One kind of the power-ups in *NerdHerder,* "Stealth" power up, was designed to see if players could rely solely on mapping other players' physical action to their in-game action. When a player triggers the "Stealth" power-up, their hook disappears on the other team's players' screens. In the interview, players commented that they tried to infer where the other player's hook was by their physical movement, but it was not precise because the dangling fishing line physics introduced unpredictability in mapping a players' hand position to their hook. In this case, although the game input mapping was intuitive when there was on-screen visualization, it was still hard without it. This game mechanic can be improved by using a direct, one-to-one mapping between players' device position and their in-game representations.

Intention

In the Norman's model of 7 stages of action, intention (or goal) is the starting point for a person to impact the world through their action and receive corresponding feedback (Norman, 1988). In game design, to create meaningful play that has discernable and integrated action-feedback loops (Salen & Zimmerman, 2004), game designers create moment-to-moment, minute-to-minute, and hour-to-hour goals (Fullerton & Hoffman, 2004). Players get engaged in a game through turning these goals defined by the game into their own intentions.

Beyond setting up group goals, the role of intention in social play is still under-explored but has great potential. *Firstly*, human beings are wired to understand the intention associated with the actions of others. Neuroscientists have found that mirror neurons code the intentions associated with the observed actions in a context (Iacoboni, 2009), which is why people can understand others' goals without verbal communication. *Secondly*, intention happens before the action (as shown in Norman's model of stages of actions), which can be effective for players to counteract. *Thirdly*, the mapping between the action and intention can be playful. Players can convey a pretend intention through their actions. For example, players bluff in card games, and make fake moves in competitive sports such as soccer and basketball. It is different from a foul because they did not disobey rules. Instead, it's seen as an advanced skill because the manipulation of the intention and action mapping adds more cognitive load for the performer to execute and increases the difficulty for an observer to discern.

These reasons above demonstrate why game designs that leverage a players' ability to act out and identify intentions is important for social play. When digital games adopt reality-based interfaces, the actions that players perform are often easier to observe with physical movements, hand and arm gestures, and verbal communication as game input. There are great opportunities for designers to create fun experiences by matching the affordances of reality-based interfaces and the cognitive and social skills of players. For example, in the user studies with *NerdHerder* and *BragFish*, players actively leveraged the prediction of intention when confronting other players. In *BragFish*, players observed the body posture of the other person and listened to the sound cues made by the device, to predict whether the other player was about to catch a fish. These observations prepared them for the next move of ramming their boat to steal the fish. In *NerdHerder*, when players observed that someone got the "stealth" power-up (as signaled through a sound effect and on-screen digital particle effect), they understood that they need to be prepared for the next action—the person who just got the power-up was about to chase after the opposing team's players.

Enabled by reality-based interaction, game designers have more choices when using intention as a design element:

- The modality of the actions: are the actions performed on the screen or in the physical world (with body movement and verbal/non verbal utterance)? How expressive are they?
- The observability of the actions: longer actions tend to reveal the intention more than shorter actions. Body actions tend to draw more attention than finger movement. How much information is revealed in the action and how observable is it? How do we support enabling players to hide their intention when required?

- The mapping between the action and intention: Is the mapping precise or fuzzy? One-to-one or one-to-many or many-to-many? Can the players manipulate the mapping or not?

In a HAR game, information can be hidden on the private display. But such information can be given away with body movements or during communication. This loose connection between the information hidden on devices, and actions that can be used to identify intention, can foster emergent social play and enhance suspense and tension.

Attention

Figure 34. A crowded information space (a screenshot from a futuristic video titled “Augmented (Hyper) Reality: Domestic Robocop” by Keiichi Matsuda (Matsuda, 2010))

Attention is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention is a scarce resource, and has been referred to as “the allocation of processing resources.” (Anderson, 2004) Although augmented reality can bring a large amount of information to the visual field (see Figure 34), the question is, how to make sure that the information is not distracting, but supporting users’ tasks and enhancing their experience. In social play scenarios attention tends to be distributed between individual and group activities (Voida et al.), between one’s phone screen and other players’ behaviors, and between the digital objects and the physical space. When players only focus on their individual activities, they tend to have parallel play as defined by Parten, playing with similar objects, clearly *beside* others but not *with* them (Parten, 1932). To encourage other forms of social play that involve more in-depth interaction, researchers and designers also need to support the mutual focus of attention among players (Collins, 2004).

To encourage users to pay attention to one another and joint activities/objects, game design needs to 1) allow players to have attention spare during the interaction; 2) provide sufficient motivation for players to join attention. For example, in an early version of *NerdHerder*, the game pace was faster: objects re-spawn frequently, and the game characters move around faster. Players considered the game as "frantic"/"busy", and there was little attention spare. We slowed down the game, which in-turn helped players to pay attention to activities that involve more complicated cognitive process involving other players, such as coordination, competition, and assistance.

To support 2), game design can encourage players to pay attention to others or pull attention from others. One way to encourage players to pay attention to each other is to increase the importance of estimating others' intentions. As discussed in the previous section, human beings have the skills and neurological basis to guess other's intention based on their behaviors, which requires them to pay close attention, observing others' actions and listening to others. For example, in *NerdHerder*, the distance-based power-ups require players to pay attention to one another's physical/digital location. Since the power-up only work within a certain distance, the player who holds it needs to chase after a target, while the players from the other team need to pay attention to the chaser to avoid being attacked. In this case, the performance depends on whether one is aware of the others' location.

To pull attention from other players, a player can use verbal and gestural cues and leverage objects. In *AoD*, players collaborate to defeat the common enemy, but they are not motivated to identify what the other player was doing. Instead, many groups adopted the divide-and-conquer strategy. They only called for the other collaborating player's attention when help was needed. In this game, because the physical pieces were directed mapped to digital objects, players used the physical objects, pointing gestures, and brief verbal reference to get the teammate's attention. However, verbal communication may attract the competitors' attention. In *NerdHerder* user study, the information addressed to the teammate was taken advantage of by the opposing team, which shows a need to "backend channel" for secretive communication.

The literature shows that eye gaze and identifying intention are two main skills for supporting joint attention (Moore & Dunham, 1995). The latter has been integrated in the game design choices in this thesis. However, in an HAR game, most digital activities happen on a screen that is hand held and focused on by the player. Consequently, it is still hard to integrate eye gaze as part of the gameplay. Games that free eye gaze from the device to people would have a new design space. In recent years, indie game community start to explore this space of face-to-face interaction in digital games, using the digital devices as peripherals rather than the center of attention (Wilson, 2011) (e.g. J.S. Joust, see Figure 35). Another alternative solution that may come from technology improvement is the optical see-through head mounted display. Players can have more direct eye contact with such kind of interfaces.

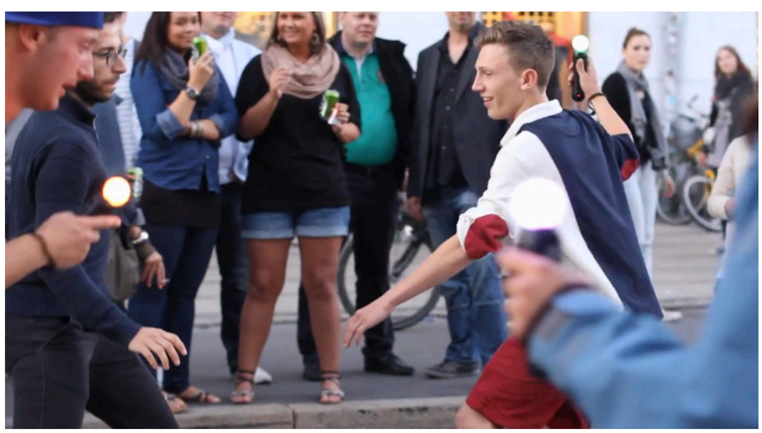


Figure 35. Gameplay during J.S. Joust (from: http://gutefabrik.com/joust.html)

Emotional Contagion

Emotional contagion is the phenomenon that people are very susceptible to one another's moods (Hatfield et al., 1994). It is:

> "the tendency to automatically mimic and synchronize expressions, vocalizations, postures, and movements with those of another person's and, consequently, to converge emotionally."(Fischer et al., 1990)

The discovery of mirror neurons provides biological evidence of how simulation of others emotions happens in an unconscious, automatic way (Iacoboni et al., 1999). Emotional contagion is also part of the social play framework by Isbister, explaining the positive loop in the group that leads to the mood elevation (Isbister, 2010).

Among the three games created during this thesis, there are more emotional stimuli in *NerdHerder* than in *BragFish* and *AoD*. In *NerdHerder*, the theme and characters design (including models, sound design and animations) here intend to be humorous and relatable, prompting players to comment on and joke about the game content. The "vividness" (Steuer, 1992) is higher in *NerdHerder* with these designs. Players' emotion expressions around these design set a tone for the game to be cartoony, funny, and slightly sarcastic. Empirically, the frequency and intensity of emotion during *NerdHerder* are much higher too. Comparatively, in *ARt of Defense*, the characters are abstract and simple looking; players' reactions were more rational and less comical (see Figure 36). The reactions to different game design shows how the character design and theme of the game can affect players' emotions (Isbister, 2006). In social games, one player's emotional responses can become stimuli for other players, reinforcing the "shared engrossment" among them (Goffman, 1961).

Figure 36. Comparison on enemy design in NerdHerder (the Donut King) and ARt of Defense (the red and blue cubes with angry faces)

Although the emotional contagion is an automatic and natural process among players, game designers need to consider what emotional stimuli should be integrated in the game, and when it is appropriate to use them. The emotional stimuli are 1) categorized as positive and negative, and 2) predispose people to bivalent behavior (e.g., approach or withdraw) (Hatfield et al., 1994). They change not only how a user may feel, but also how they behave. Interaction Ritual theory proposes a model of how shared emotion and mutual focus of attention reinforce each other. In other words, social interaction is a process of building up, sharing and elevating the emotions; and paying attention to shared activities and objects begins and enhances this process. The analysis in Chapter 9 on *NerdHerder* player interaction shows examples of this process during HAR games. For example, in the game event where the Donut King attacks the Nerds, players shared their frustration by raising their voice, cursing and laughing together. In one group, this shared emotion led to players changing the rules to play collaboratively between teams. This shows how shared emotion changed players' strategy and motivated them to adapt the game rules for the group. In *AoD*, the build-up process was designed in a different way. As the game proceeded, more enemies came out in a faster pace. This led to elevated sense of urgency, which increased the pace of actions and more requests for assistance and communications about collaboration.

Emotions are conveyed through facial expressions, vocalization, posture, and movements (Fischer et al., 1990). When the co-presence between players are mediated through technology, such as voice and video chat, or through the bodies and faces of avatars, much of the fidelity of these channels of expression and hence understanding of the emotions are missing. Moreover, the digital representations of players do not have emotional contagion abilities built-in. In contrast, co-located games have the advantage of automatic emotional contagion. This is the main reason why games leveraging the bodily communication, expression, and interaction can increase the social play enjoyment in shared hybrid spaces.

Summary

In summary, the five concepts: “co-presence”, “mapping”, “intention”, “attention”, and “emotional contagion” emerge as important framing constructs from my multiplayer Handheld Augmented Reality game projects. I use them as lenses to reflect on the three HAR games that my team and I developed. Although these concepts originate from the cognitive science and sociology literature, I discuss them in the context of co-located hybrid gaming and social experience. These concepts also map out design opportunities and challenges for social games with Reality-based interfaces, which is discussed in further detail in the “future work” section in the next chapter.

CHAPTER 11

CONCLUSION AND FUTURE WORK

This thesis focuses on understanding and designing social play in a shared hybrid spaces enabled by Handheld Augmented Reality (HAR) interfaces. The overarching research method is Research-through-Design (RtD), using game design as core knowledge inquiry methods, and grounding the design with sociological theories, empirical understandings, and the affordances and constraints of HAR interfaces. My team and I designed, developed and playtested three multiplayer HAR games. I conducted user studies on these games to collect and analyze interpersonal behaviors and experiences during these games. The findings show how players interact with one another by integrating physical and digital interaction channels, and how design choices support and trigger interpersonal behaviors.

In this chapter I first evaluate the quality of my work as one Research-through-Design work, then summarize my contribution in respect of multiple research communities. Finally, I discuss three threads of future work inspired by this thesis.

Evaluation of This Research-through-Design Work

The overarching research method of this thesis is Research-through-Design. Zimmerman et al. started the discussion about how to evaluate RtD research by proposing four dimensions, including process, invention, relevance, and extensibility (Zimmerman et al., 2007). I evaluate and reflection on my thesis work along these four dimensions.

Process

This criterion is about reporting enough details about the interaction process, rationales of design decisions, and the reasoning behind the method choices. I have reported:

- Design rationales: For each of the three projects, I report design rationales and goals that were turned into design choices. These rationales have a common goal of encouraging more frequent and enjoyable social interaction. Some of them are more informal, e.g. the *BragFish* design rationales were based on what we learned from other AR games and what we believed the affordances of AR were for the users. Some are based on theory, and get integrated in the game design in a more formal way, e.g., multiplayer *NerdHerder* systematically turns a list of theory-based design guidelines into design elements.
- Design iterations: For two of the individual projects, *ARt of Defense* and *NerdHerder*, I report the major iterations that we went through. For example, In *ARt of Defense*, the design team iterated on the game control of tower-initialization. The design team decided to simplify the user interaction by using a shape-recognition approach rather than a sketch-based interface. Although the latter was a more advanced technology, it was too complicated for a user to use by one hand consequently. Therefore, it was replaced by a simpler interface in later iterations. In the multiplayer *NerdHerder* design, the team agreed that iteration was an effective method for improving the design, and I discussed the iteration cycle that we repeatedly conducted during the development process.
- The choice of research methods and why: Throughout the dissertation I state the reasons why I choose certain research methods. From the high-level method of Research-through-Design and theory-based design, to medium-level methods of lab-based studies and video analysis, to the choice of specific tools, I discuss how these methods fit with my work, and why I choose this method over other methods.

In summary, this thesis reports the reasoning and rationales behind our research and design decisions, supporting other researchers and designers to analyze and build on our design artifacts and research findings.

Invention

The invention of an RtD work is demonstrated through a novel integration of various subject matters to address a specific situation (Zimmerman et al., 2007). To achieve this goal, researchers need to conduct an extensive literature review that situates the work and details the aspects that demonstrate how their contribution advances the current state of the art in the research community. (Zimmerman et al., 2007)

One major difference between the game design in my thesis work and commercial games is the research goal behind this work. My work is not just about making an enjoyable or popular game, but to understand the connection between game interface and player experience. To achieve this goal, I have 1) performed a thorough review on prior research and AR games; 2) aimed to answer research questions through design; 3) sought a balance between the quality of implementation and the research outcome.

First, to keep in tune with the best practice and research in HAR games, I compare and analyze all the previous research and commercial AR games, extracting design patterns where there are repeated solutions to repeatedly appearing design challenges in these games (Xu et al., 2011b). My colleagues and I have played the majority of the AR games that we had access to and learned from them. For example, the design of *BragFish* was influenced by an informal playtesting on *the Eye of Judgment* that I did in 2008.

Second, these games in my thesis are designed to explore unanswered research questions. Beyond the goal of making enjoyable games, they each answer research questions. *BragFish* and *ARt of Defense* are our earlier probes into the space of HAR games, which answer the research questions around what kind of the social behaviors emerge during multiplayer HAR games. More specifically, *BragFish* focuses on how communication channels affect social presence, while *ARt of Defense* explores the role of tangible interaction. Multiplayer *NerdHerder* is designed with the research goal of testing the usefulness of sociological theory-based design guidelines. All the games are designed to advance our understandings of social play behaviors, and how to design for them.

In relation to the second point, I strive to balance between the quality of implementation and the research outcome, given limited time and resources. These games in my thesis work were all designed and developed in research institutes with small student teams. However, my teams and I are well-aware that good ideas do not justify poor implementation. In fact, if the usability and playability of a game is compromised, it can harm the validity of the research on social play. Hence, we spent a great amount of time enhancing the core game control and feedback. For example, we had at least 5 major iterations on the *NerdHerder* game control mechanism to reach a satisfactory solution. We then gained more external validity by releasing the games to mobile application markets. In both Android and iOS markets, *NerdHerder* receive positive ratings (~4 out of 5 with 47 ratings at the time of writing). But there are still flaws in this game that we could have spent time and resource improving. In the end, we developed a complete game prototype that has a solid core action-feedback loop (Salen & Zimmerman, 2004) and supported answering our research questions.

Relevance

Instead of evaluating the validity of the work, Zimmerman et al. proposed that relevance is a goal more suitable for RtD research (Zimmerman et al., 2007). A design needs to make the state change that the community care about and consider as “preferred.” (Zimmerman et al., 2007)

With 55% of gamers playing games on handheld devices and 65% of gamers playing with others in-person (ESA, 2012), this research on social handheld AR game is addressing the design needs and challenges for a large population.

Moreover, it is challenging to turn reality-based interfaces that encourage physical, 3D, and gestural interactions into fun, enjoyable, social games. Even big companies make mistakes when designing game controls that are not a good fit with the game interface and platform. This work provides an in-depth case study on how to integrate the HAR interface in every phase of game design.

Extensibility

Extensibility is defined as the ability to build on the resulting outcomes of the interaction design research: either employing the process in a future design problem, or understanding and leveraging the knowledge created by the resulting artifacts (Zimmerman et al., 2007). My research takes a player-centric stance, using sociological theories to understand what the components of an enjoyable social interaction are. I chose this approach to transfer findings from one game to another.

This kind of player-centric approach is needed for a field with fast technology innovations, such as AR technology. Compared to the software and hardware for making AR applications, the technology has made quantitatively and qualitatively significant changes. Back in 2007, *BragFish* ran 12-15 frames per second on Gizmondo (one of the fastest handheld devices at that time), while these days *Qualcomm Vuforia* can run ~50 frames per second on many Android and iOS devices. From the black-and-white fiducial marker based tracking, to natural feature based tracking, to the markerless SLAM tracking system (Bailey & Durrant-Whyte, 2006), there is more diversity and flexibility in the user interactions supported by AR.

This work takes different HAR interfaces as a design material, integrating affordances and constraints of each kind of them into game design. While the technology may change fast, the core of my design is player-centered. The human process and ingredients of an enjoyable social experience are relatively stable compared to technology changes, although they can be transformed into different forms with new interfaces and new design. The theory-based analysis and design are applicable when working with other AR interfaces (e.g. Head-mounted Display (HMD)) and other reality-based interfaces. The extensibility of this work is further discussed in the future work.

Contributions

In summary, this thesis is a multidisciplinary research that combines game design, sociological theories, and empirical studies into the multiplayer HAR games. It contributes to the multiple research and practice communities in the following ways.

- *To the game research and design communities*: providing new design examples in the shared hybrid space
- *To the HCI and game studies communities*: enriching the empirical understandings on co-located social play
- *To the sociology and game research communities*: adapting and applying sociology theories for co-located social play
- *To the AR and game design communities*: generating a list of tested theory-based design guidelines for HAR games
- *To the HCI and game research communities*: a case study on connecting reality-based interface with social play experience in a shared hybrid space

In the following sections, I will elaborate each of these contributions in greater detail.

To the game research and design communities: providing new design examples in the shared hybrid space

As RtD work, this thesis communicates to the game design and research communities through the game prototypes we created, including *BragFish*, *ARt of Defense,* and *NerdHerder*. In contrast to designing games as commercial products, the design in my thesis work embodies researchers' and designers' visions and theories, with the goal of encouraging more enjoyable social play. The challenges of supporting social play on small mobile devices motivated us to leverage a new kind of mobile interface—Handheld Augmented Reality—that has the potential to bring social play from small private devices into a shared hybrid space. In the game design, we shift the handheld game interfaces from finger-based control to embodied control in the hybrid space. This change not only turns physical actions into game input, but also supports players in observing one another and leveraging their co-location in the physical and digital space.

This thesis has reported in great detail about the design rationales, iterations, and choice of research methods. With this information, other designers can create new HAR games based on the design lessons learned and reported in this thesis. Researchers can also conduct user studies on such kind of HAR games, comparing with and synthesizing the findings I present in this thesis. For example, Sony Mobile recently conducted a user study with *NerdHerder,* and their studies and findings are directed towards their own research and practice goals (personal communication with Sony Mobile researchers).

These design artifacts also serve as communication objects for game research and design communities. My colleagues and I have presented these game prototypes at various conferences in game development and research, Augmented Reality, and HCI areas, including GDC (Game Developer Conference), ISMAR (International Symposium of Mixed and Augmented Reality), DiGRA (Digital Game Research Association conference), ACE (Advances in Computational Entertainment), FDG (Foundations for Digital Games), CHI (Human Factors in Computing Systems). Through playing and commenting on our game prototypes, other researchers had many in-depth discussions with us, such as: how to scaffold the learning of new control paradigm, the gender issue in game design, the embodied interactions and what is challenging about designing for embodiment, etc. These discussions are meaningful to my own research and may inspire other researchers as well.

To the HCI and game studies communities: enriching the empirical understandings about co-located social play

The game research and HCI communities have been interested in understanding the emergent social play behaviors that are enabled and encouraged by novel play experiences. The HAR games that we designed and developed provided platforms through which players exhibited new kinds of interaction and communication behaviors.

I adopt and combine a myriad of qualitative and quantitative research methods and tools to understand moment-to-moment social play during gameplay, with the focus of connecting our design considerations and implementations with the observed interpersonal behaviors and experiences. Based on empirical data, this research provides detailed and rich accounts of emergent social interaction behaviors that happen within a shared hybrid AR space.

The findings show that the subjective experience of co-presence ("being there together") is not guaranteed by players' physical or digital proximity. Instead, to support the creation of co-presence, designers need to provide incentives for players to join attention on the same object/activity/player and share the mood with each other.

The user studies also show that the tight registration between physical and digital objects, which is the core feature of an AR interface, supports players integrating their perception and action in the physical world with those in the digital world, enhancing players' sense of co-presence and shared awareness. Moreover, it supports the intuitive and discernable mapping between one's physical action and in-game state change. This mapping is the foundation for a player to infer others' intention before an actual action happens, which provides incentives for players to pay attention to each other. In the physical space, where players are aware of one another's action and game state, "emotion contagion" is natural and automatic. Taking advantage of this natural human ability, the game design can trigger this process through emotional stimuli that are integrated in the gameplay.

In the context of HCI and interaction design, these empirical understandings are rich sources for design implication. For example, in the process of designing three games and their iterations, our design team turned empirical understandings in previous prototypes into the design choices of the next one. This continuity supports the improvement in the quality of HAR game design.

In summary, this research provides detailed and rich accounts of the anticipated and emergent social play behaviors in a shared hybrid AR space.

To the game research and sociology communities: adapting and applying sociology theories for co-located social play

The contribution of a theory can be multi-folded, including its descriptive, rhetoric, inferential, and application powers (Halverson, 2002). Sociological theories have been used in game research for their descriptive and rhetoric power, explaining a phenomenon with its theoretical frameworks. One of my thesis work's contributions is to adapt and apply the theories from sociology to guide the design of technology in a different application domain (i.e., co-located social games.)

Specifically, I choose the Interaction Ritual theory (Collins, 2004) and Frame Analysis (Goffman, 1974) from the sociology literature. Although neither theory was created specifically to help explain social play, they have shed light on games research (Fine, 1983; Stromberg, 2009). I bring them to a specific sub-domain of play and games: co-located social play in a shared hybrid space.

Compared to the scenarios where the theories were generated, co-located social games may assign physical actions and verbal communication new meanings, define the incentive structure for players to pay attention to each other, and encode the communication and expression channels that players can use in the game interfaces. Facing with these differences, I adapt the theories by reanalyzing existing empirical data on co-located games from the game research, HCI and CSCW literature and generate design guidelines for co-located social play based on the theories.

The theory-based design guidelines for co-located social play include 1) natural mapping, 2) motivating the use of bodily presence in the game, 3) signaling, 4) displaying information to spectators through bodily enacting, 5) common game objects that are independent of players, 6) motivating players to pay attention to each other, 7) game-generated shared target, and 8) player-generated shared experience.

Although these guidelines are generated for co-located social play in general, I interpret them with a focus on reality-based interaction in which players can leverage their existing physical, body, environmental, and social skills, and map their physical and social actions as the gameplay.

I chose a subset of the design guidelines and implemented them in the multiplayer *NerdHerder* game. In this team-based competitive game, we focus on designing an intuitive mapping between players' physical maneuvering of mobile devices and the core game control, dangling a digital hook from the device camera; we also design game mechanics that encourage players to pay attention to their teammate and the opposing team, and to share the mood triggered by joint activities. The diversity and frequency of social interactions and players' self-reported survey feedback shows that *NerdHerder* is an enjoyable and social game, proving the usefulness of the sociological theories in designing a usable, playful, and social game for co-located small groups. Further analysis reveals how the HAR game interface and the implementation of the theory-based design guidelines support and trigger these inter-personal behaviors and game strategy choices.

Because these design guidelines are grounded on the sociological understandings of human behavior, they are not limited to one specific choice of technology. This approach uses the human-centered perspective to understand why certain game designs do or do not work. Therefore, game designers can transfer what they learned in one game to other games.

Equipped with the theory-based lens, this thesis demonstrates how researchers and designers can critique their own and others' design examples constructively, understanding which design choices are better, and why. As Gaver suggested, RtD research might better view theories as "*annotation of realized design examples, and particularly portfolios of related pieces*." (Gaver, 2012). This theory-based approach is proven to be fruitful in this thesis work.

To the AR and game design communities: generating a list of tested theory-based design guidelines for HAR games

AR is a nascent and fast-developing domain. My work speaks directly to game designers who are interested in leveraging AR interfaces to create fun, engaging and social experiences. As commercial game platforms and smart phones have started to have the capabilities needed to support AR interfaces, many designers and developers have become interested in this design space.

The theory-based guidelines provide a foundation and starting point for designing such applications and games. Moreover, my discussion on the sociological theory is contextualized with game design and practices iterations. The usefulness of these design guidelines is verified through the player experience study. In a broader sense, my work can be useful for designers who are interested in creating games that seamlessly integrate virtual and digital objects with the physical environment.

These design guidelines can be used as inspirations for new design, to explore uncharted design spaces, and to critique and improve existing design.

To the HCI and game research communities: a case study on connecting reality-based interface with social play experience in a shared hybrid space

Although game designers and commercial games are actively adopting many reality-based interfaces, the HCI research related to such interfaces does not easily transfer to the domain of game design due to differences in goals and values. Beyond usability, a game needs to fulfill playability and social play goals. My work takes one type of reality-based interface (HAR), and reports the challenges encountered and solutions developed when designing such games.

Beyond the scope of multiplayer HAR games, this thesis work explores how a reality-based interaction paradigm can create hybrid co-location among players by the case study on multiplayer HAR games. In this hybrid physical-digital space, the boundaries between the digital and the physical, the virtual and the real, are blurred; players' co-existence in one space can be translated into the other. By designing and studying games that leverage the shared hybrid space, I show how people distribute and integrate their attention between individual and group goals and between the digital interface and the other players, and how their emotion and enjoyment is elevated through the process of interaction in this hybrid space. The player experience is co-created by the designer and the player—the designers create situations that stimulate certain inter-personal behaviors and emotions through game mechanics and rules; the players innate needs and skills enable them to play the game. Through a player-centric research through design method, this thesis work bridges our understanding of inter-personal behaviors and the affordances of HAR interfaces.

With the evolvement of HCI and Ubiquitous computing, the diversity of reality-based interfaces is increasing, giving game designers a wide variety of reality-based game interfaces to choose from. The choice of how to leverage these interfaces needs to be based on a deep understanding of the affordances and constraints of each of these interfaces under certain game genres, context of play, and target audiences. The RtD method adopted in this thesis provides an example of how to integrate multiple disciplines' knowledge and research activity to form an effective research agenda.

Future Work

Designing Social Play with (Other) Reality-based Interfaces

Although this thesis focuses on one kind of interface, Handheld Augmented Reality, the theoretical foundations in this work are applicable to social interactions in the a shared hybrid space enabled by reality-based interfaces. These concepts, including co-presence, mapping, intention, attention, and emotional cognation are originated from cognitive science and sociology, to understand human behaviors in general, and have been adapted to social gaming context in this thesis. Game designers can use these theories and concepts as lenses to reflect on and compare game examples, find the unexplored design spaces, and create novel gameplay experience.

For example, to compare two physical dance games, Dance Central (DC) on Kinect (Dance Central, 2010) with Yamove! by Game Innovation Lab , we can use the descriptive and rhetorical power of these theoretical concepts. In DC battle mode, players map their physical actions to their in-game avatars. The mapped avatars are displayed side-by-side on the screen, occupying the visual attention for each player. Because of the fast-paced gameplay, players have little attention spare. Moreover, players are not motivated to observe others because they do not gain performance benefits by doing so, with the exception of the short free-for-all phase. In the most part of the game, players focus on their own movements and do not need to pay attention to what the other person is doing. In the free-for-all mode phase, players could adopt the strategy of observing the other player and choose to pick a different movement sequence or mess with their goals. However, this strategy is not always working and a player can still get high score by perfecting their own moves and ignoring the other player. But the visibility of the screen and direct mapping between players and avatars provide an enjoyable spectator experience. The exertion of dancing activities also increased the excitement level in the crowd. Comparatively, in Yamove, the goal is to mimic and synchronize with others' actions; it requires players to pay close attention to other players' physical actions. Players' eye gaze is freed from screens to the other player's physical actions in the space. This creates more social interaction than other console-based social games (Isbister, 2012)

Above comparative analysis shows an example in which the theoretical concepts extracted from co-located social play are used to reflect on other social games created with other reality-based interfaces. Although social play is complicated phenomena depending on the game genre, mediation channels between players, and players' engagement (Stenros et al., 2009), these concepts provide a set of dimensions that have been found to be fundamental to social play experience. Along these dimensions, further research can create a theory-based taxonomy for social play.

The technology evolution is fast and its diversity is increasing, but the cognitive and social skills people rely on for effective and engaging social interactions are relatively stable, with new variations and expansions supported by new medium. The next forthcoming AR technology is Head-Mounted Displays that are comfortable to wear continuously and move around with. With HMD, the view of the 3D world is aligned with a users' body movement, and the digital objects are registered on the real world in the room or city scale. Other than creating Laser Tag style games in living rooms, what kind of the social play matches with the affordances of HMD interfaces? To address this problem, the challenges we have encountered in HAR games still apply, such as intuitive mapping from players' physical movements in the real world space to game state changes in the digital space, establishing inter-referential awareness for a common reference system, and directing players attentions to other players' movements and verbal communication. The theoretical concepts can continue to inspire the design for social play in a shared hybrid space. Moreover, the iterative, hands-on, player-centric design process needs to be applied in the process of exploring and experimenting with the new design material of HMD. The specific affordances and constraints of the HMD hardware and software need to be integrated in the game mechanics and rules.

This thesis focuses on co-located social play. It has not explored the remote players who may share a physical-digital space. For example, players can control a robot or a projected character that exists in the same physical space as others. This opens up new arenas for social play. What does the physical proximity mean between a human and the digital representation of another human? Could the emotion synchronization and contagion happen between them also? Do the sociological theories for human-human interaction still apply? The new design space enabled by different interaction and communication modalities opens up more interesting research questions that we can explore in the future.

Long Term Effect of Social Play

The scope of this thesis is limited to the moment-to-moment interactions during the gameplay. The longer-term effect of gameplay, such as enhancing social bonding between players (Mueller et al., 2003), transforming the social relationships (Salen & Zimmerman, 2004), the evolving lifelines of the social relationships built between real and game worlds (Taylor, 2006; Xu et al., 2011c), and building the online game communities (Ducheneaut et al., 2006; Kolo & Baur, 2004), is not researched within the scope of this thesis. But this is not due to the limitation of the Interaction Ritual Theory that is adopted and adapted in this work. In fact, the IR theory targets for the connection between micro- and macro-sociology through the continuity between different interaction sessions. When an interaction ritual is formed, it is repeated regularly among participants. The emotional energy is the subjective experience that one gains from the previous interactions, and this helps to decide whether a person chooses to join the interaction ritual again. As a longer-term outcome, a successful interaction ritual enhances the social relationships between participants, increases group solidarity, reinforces the symbol for the group, and increases the sense of morality (Collins, 2004).

A future extension of this thesis is to conduct a longer-term study on repeated and regular social games, such as with tabletop role-playing game hobby groups, regular meet-ups in online game worlds, and LAN parties. IR theory can support the analysis of this long-term regular gameplay because the theory connects the here-and-now interactions during a game and the long-term effects of gameplay for individuals and groups. This work will be useful to understand how players embed games as part of their everyday life and whether (and how) the games are impactful in the long run.

Another method to study long-term social play is through log data. For example, the single player *NerdHerder* game collects some gameplay logs from players who are willing to join our study. We have gained a large amount of data (~8,000 logs from play sessions by Oct 14, 2012) showing gameplay change over time. Using the game log data collected online for multiplayer games, we can study long-term change of gameplay patterns and record social interaction histories. This can become a rich mine for researchers to investigate how the social networks among co-located AR players evolve, the physical movements players have in relation to each other, and the patterns across multiple game sessions. The advantage of this approach is the ability to quickly collect a large amount of data with little intrusion to the user's natural environment. The downside of this approach is a lack of understanding about the user's environments and their reasoning behind their actions.

Using Social Games as Research Tools for Collaborative Work

Games provide self-contained systems that people are authentically engaged in. Multiplayer games in a shared hybrid space have a lot in common with computer supported collaborative work—users integrate the digital and physical information together to perform better. Researchers may consider using social games as platforms and research tools to research collaborative work, such as finding unsolved issues in collaborative work, testing out new design and technical solutions for group interaction, and transferring the knowledge learned from social games to work. Researchers have started to use games as research tools. Bainbridge discussed using online worlds for advancing knowledge in social, behavioral, and economic sciences. His summarizes the research examples and methods by scientists who conduct experiments and observational ethnography on Second Life and World of Warcraft (Bainbridge, 2007). Online games provide a platform for researchers to understand realistic behaviors and choices in a digital economic market and conduct large-scale studies, which are a lot harder to achieve in real life. HCI researchers also start to leverage games as platforms to understand group behaviors and design for them. Replicating the interactive scenarios between people is oftentimes difficult and participants may feel awkward and forced in an artificial interaction scenario (Dabbish et al., 2012a; Dabbish et al., 2012b). Using social game environments can avoid these problems and provide a more natural environment for participants to be engaged in. For example, Dabbish conducted a series of user experiment on Facebook games, World of Warcraft, and online card games, to understand how communication, group identity, turnover rate, affects certain aspects of group interaction (e.g., commitment, social presence, participation level etc.) (Dabbish et al., 2012a; Dabbish et al., 2012b)

The studies of shared physical-digital games in this thesis work have shown how the attention to other players, co-presence level, and shared emotion affect the enjoyment and game experience. These dimensions of social interaction behaviors are also fundamental to other scenarios of social interaction, including collaborative work. Some of the findings in my work resonate with those in CSCW. For example, the way players refer to and communicate about physical-digital objects in *AoD* study is similar to Gergle and Clark's findings on how people refer to objects in a collaborative work scenario using HMD. In both cases, users leveraged both their bodily cues (in their research, eye gaze and physical movements; in *AoD* study, hand gestures and object manipulation) and verbal cues (in both cases, deictic pronouns, such as "this", "that", "here", "there"). Our findings with *NerdHerder* show that players construct a shared awareness through bodily movements and gestures, on-screen game events, and verbal communications. Correspondingly, in Gutwin and Greenberg's framework for workspace awareness, they summarize three ways that users construct shared awareness, including "bodies and consequential communication", "artifacts and feedthrough", "conversation, gesture, and intentional communication" (Gutwin & Greenberg, 1999). What we find in *NerdHerder* align with these three ways of supporting workplace awareness.

While the cognitive, behavioral, and sociological dimensions of social play are similar to those in collaborative work, designers and researchers need to be aware of the difference of goals in a game compared to work. Games are not created to serve external functions; people choose to play a game because it is enjoyable experience. But collaborative work typically has productivity goals. For example, to encourage players to share emotions, we designed *NerdHerder* to be goofy and funny, and the artificial intelligence in the game intentionally gets in the way of players. Players may get frustrated once in a while. Such kind of design likely does not make sense in work scenarios. The metrics for evaluating a good game experience is very different from the metrics for work. When using social games as research tools, researchers need to be aware of this difference, especially when borrowing an existing game for specific research goals.

APPENDIX A

OBSERVABLE SOCIAL INTERACTION BEHAVIORS LIST

Behaviors along these two dimensions

1.Ways of expressions: Speech/non-speech utterance/gestures/body-space arrangement

2. Purposes of the actions: Emotional: empathy/display; Learning; Performance: strategy; Shared awareness; individual enjoyment vs. group

1. Emotional contagion
    a. Empathic gestures
    b. Laughing together
    c. Burst of emotions (negative, booing)
    d. Display, taunting, trash talking
    e. Physical feedback: Body contact; movement; have fives

2. Collaborative learning
    a. Seeking help
    b. Helping teammate
    c. Helping the other team
    d. Instrumental gestures
    e. Share information

3. Increasing awareness
    a. Peak over the shoulder
    b. Verbal questions
    c. Checking other's status
    d. Report progress
    e. Shared success and failure
    f. Stitching individual views together

4. Strategy
    a. Getting in the way (to annoy or to strategically occupy positions)
    b. Verbal discussion
    c. Local strategy

    d. Global strategy

5. Collaboration
    a. Reminding other person
    b. Share information
    c. Sharing how-to
    d. Cope with skill difference
    e. Define roles
    f. Instructions
6. Competition
    a. Display, taunting, trash talking
    b. Get in the way

7. Reflections
    a. Discuss the score
    b. Discuss the gameplay
    c. Shared game history

8. Joking
    a. About the game content
    b. Trash talking
    c. Moving funny

9. Out of game topics

APPENDIX B

SEMI-STRUCTURED INTERVIEW GUIDE

Post-game Interview Guide

1. How much are you aware of your teammate's action and status in the game?
    a. What do you think of their performance?
    b. Did you do anything to coordinate?

2. How much are you aware of the other team's actions and status in the game?
    a. What do you think of their performance?
    b. Do you have strategies against them?

3. What are the strategies you have developed during the gameplay (for what condition)?

4. Did you play games with these friends before?

5. What co-located games did you play before? How is this game compared to previous multiplayer game experience(s) that you sit together and play?

6. What do you think of the AR interface in the game?

7. If you are the designer, what will you change in the game?

APPENDIX C

SOCIAL PRESENCE SURVEY

Group ID___ Player ID____

Please answer the following questions based on the 1-7 scale:

1.1. How much social interaction did you have with *your teammate* during the game?

1	2	3	4	5	6	7
None			Medium			All the time

1.2. How much social interaction did you have with the *other team* during the game?

1	2	3	4	5	6	7
None			Medium			All the time

2.1. How much are you aware of what's going on for *your teammate*?

1	2	3	4	5	6	7
Not at all			Medium			very-well tuned

2.2. How much are you aware of what's going on for *the other team*?

1	2	3	4	5	6	7
Not at all			Medium			very-well tuned

3.1. How much do you think *your teammate* observes you during the game?

1	2	3	4	5	6	7
None			Medium			All the time

3.2. How much do you think *the other team* observes you during the game?

1	2	3	4	5	6	7
None			Medium			All the time

4.1. How much is your play action (e.g. strategies, choices) influenced by the action of *your teammate*?

1	2	3	4	5	6	7
None			Medium			All the time

4.2. How much is your play action (e.g. strategies, choices) influenced by the action *of the other team*?

1	2	3	4	5	6	7
None			Medium			All the time

Please rate how much you agree with the following statements:

1. I felt connected to the other players.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

2. When the other players were happy, I was happy.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

3. When I was happy, the other players were happy.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

4. I found it enjoyable to be with the other players.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

5. I felt social pressure during the game.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

6. I tended to ignore the other players.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

7. I felt being ignored by other players.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

APPENDIX D

POST-GAME PLAYER EXPERIENCE SURVEY

Group ID___ Player ID___

How much do you agree with the following statement?

- It was easy to learn how to play *NerdHerder*.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- The interface in *NerdHerder* is intuitive.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- My skills of playing *NerdHerder* have improved overtime.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- I enjoyed playing *NerdHerder*.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- Physical movements are important in *NerdHerder*.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- I enjoyed the social interactions during the game.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- I played without thinking how to play.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- I was concentrated when playing the game.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

- I would like to recommend *NerdHerder* to my friends.

1 2 3 4 5 6 7
Strongly disagree Neutral Strongly agree

APPENDIX E

PLAYER DEMOGRAPHICS SURVEY

Gender: ______
Age: _________
Player ID:_________
Group ID:_________

1. Do you have previous experience with video games that have a physical interface (interfaces the require you to move in the space)?

☐ yes ☐ no

If yes, select the systems that you have played before

☐ Nintendo Wii

☐ Microsoft Xbox Kinect

☐ Sony Move

☐ Sony Playstation Eyetoy

☐ Smart phones (e.g. iPhone, Android phones, Windows phones etc.)

☐ Handheld consoles (e.g. Nintendo DS/3DS/DSi, PlayStation Portable etc.)

2. Have you tried Augmented Reality applications or games before?

Note: Augmented Reality means viewing computer-generated graphics on top of real world objects.

☐ yes ☐ no

If yes, please specify____

3. How many hours did you spend on playing video games in the past week? ___________

4. Do you consider yourself as:

☐ A hardcore gamer

☐ A casual player

☐ Somewhere in-between a hardcore gamer and a casual player

☐ I don’t play video games at all

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